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Nothing is more noble, nothing more venerable than fidelity. Faithfulness and truth are the most sacred excellences and endowments of the human mind.—CICERO.

CONTENTS FOR APRIL, 1955

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SCHOOL SCIENCE AND MATHEMATICS

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HOW GOOD TEACHERS TEACH SCIENCE*

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What I shall do this morning is this. I shall define the nature of good science teaching, as I see it. I shall do so in terms of four major responsibilities that really good science teachers accept and discharge. Then I shall review the evidences from research and the practices of good teachers that show the general kinds of things good teachers do in the teaching process in order to achieve their goals.

It would be absurd for me to propose to you a single method of science teaching and to declare that this is how good teachers teach science. There are thousands of really good science teachers in the United States today, and their methods in any specific sense vary tremendously.

It would be futile for me to attempt to provide you with a kaleidoscopic view of the great variety of sound science teaching that exists today. There isn't time to develop a useful picture of a tithe of this during the time at my disposal this morning.

How do good teachers teach science? It is easier to define the good teacher as a person. I know, for example, that no one can be a master teacher of science without thorough understanding of at least the fundamentals of the science he professes to teach. He must more than know it in a factual sense. He must comprehend it—and that is more than mere knowing. He must have been disciplined by his science if he is to communicate the power of his discipline to his students. He must see his science as a dynamic, living force for the betterment of mankind if he is to breathe life into his teaching of

* A paper read before the Friday morning session of the Central Association of Science and Mathematics Teachers at Chicago, November 26, 1954.

young people. The good science teacher does not conceive science to be something taught statically from the pages of a textbook. The good teacher lives his science. He inducts his students into the spirit, methods, and knowledge of science that he, himself, has the personal power to communicate. To put it simply, the good science teacher has a mature grasp of his science and its meaning to his students and society. It is beyond the scope of this paper to discuss inadequacies in the education of teachers. But I cannot resist offering you a few data which illustrate a major reason why we still have poor science teaching today. Dr. Theodore Nelson of LaGrange, Illinois, recently completed a comprehensive study of beginning science teachers and their work in the state of Illinois. He found that 51% of the beginning teachers of science in Illinois did not major in *any* field of science. The training in physics of the physics teachers ranged from 8 to 55 semester hours, with a median of only 16 hours. Those teaching chemistry had from 8 to 49 hours of college chemistry, with a median of 23.5 hours. Those teaching biology had taken from 2.6 to 77 semester hours in this subject with the median at 25 hours. I am deeply concerned about the kind of science education young people are getting from our science teachers whose preparation in their subject fields is in the lower ranges of these distributions. I cannot believe that poorly trained science teachers can be really good science teachers.

Good science teaching requires more than competence in a science discipline. It requires professional insight, skills, and understanding that can only be achieved by serious and sustained professional study and practice. But to analyze these things would also require more time than is at my disposal. I mention them as I do the science competence of the teacher, simply to insist that a base line of personal competence necessarily underlies all really good science teaching. Now let me briefly define the nature of good science teaching as I see it.

The Nature of Good Science Teaching

In 1885, Poincaré stated: "Science is built up with facts, as a house is with stones. But a collection of facts is no more a science than a heap of stones is a house."

I think that there will be no argument among us on this point. Good teachers are perfectly aware that their responsibility as the representatives of science and democracy in the classroom is not discharged solely by the teaching of scientific facts; or consummated with the evidence on standardized examinations that their students can, indeed, recall, for the present, the facts as they were taught.

We who teach science are the exemplars of the philosophy and the

critical method of inquiry of science for our students. Or at least we should be. The edifice of science is built with facts, but it is the proper and judicious use of those facts, and the employment of the rigorous intellectual process by which the factual can be distinguished from the illusory that is the proper business of the inhabitors of that structure. It is only as that business is carried on that science and democracy itself can advance. The survival of the free world and its institutions, including organized science, is heavily dependent upon an informed citizenry which has come to understand and treasure the meaning of freedom; the method of intelligence; the method and philosophy of science. Herein lies a major responsibility of the science teacher today.

Good teachers accept this responsibility. They challenge, stimulate, guide, and help their students to develop the understandings, critical abilities, attitudes and viewpoints that are representative of the best in the scientific and democratic traditions. In doing so they focus a certain proportion of their attention upon the urgent problems of personal and public life. For they recognize that ours is a society where the people must determine the formation and execution of policy in matters that affect them. Good teachers strive to make their students so much at home in the house of science as Poincaré suggested it, that these young people will increasingly find hospitable living therein, will contribute to its improvement, and defend it against all detractors. They know that their responsibility is basically the same whether their students become professional scientists for simply skillful, scientifically minded artisans in the all important task of advancing the causes of freedom and humanity at home and abroad.

There are four important dimensions to this responsibility. For one thing, sound science teaching requires that we join forces with our colleagues who teach at the college level in improving the total offering in sciences for those of our students who will continue their work in institutions of higher learning. Sound college preparation is an important part of our responsibility and it is not neglected by good science teachers.

Secondly, we must wisely select and soundly organize the things we teach so that facts, principles, and broad understandings that are fundamental to sound human living in the modern world will be learned—really learned—and retained. We must be sure that our students do not leave our courses with but a smattering of ignorance sufficient for filling in blanks on standardized tests, but unusable in the affairs of life and, therefore, soon lost in the limbo that receives many inert academic learnings. Our students, generally speaking, are capable of learning far more than we have commonly taught.

But good teachers recognize that teaching which degenerates into a superficial race over facts, logically organized, but essentially alien to the experiences, interests, and needs of young people, must be questioned precisely on the grounds that it results commonly in but verbalistic knowledge of little durability or usefulness. Good science teaching is always more concerned with producing a functional mastery rather than in coverage of content.

But our responsibility does not stop even here. Even more important than the facts we teach are the abilities we may develop that will enable our students to engage, throughout their lives, in the process of self-education, and in the judicious and critical use of facts for the betterment of their personal lots and that of mankind. I am here speaking of the skills of critical thinking and the auxiliary skills of effective library usage, critical reading, and so forth. I grant you that we know all too little about these skills and how to develop them. But some aspects of the process of critical inquiry and thought are known and have clear imperatives for the instructional process. Good science teachers do not neglect these imperatives.

Even here we dare not stop. For our students are more than brains encased in physical shells. They are total personalities that hate, fear, hope, aspire, and love. It is impossible to teach just the brain. For the individual is emotive and valuative as well as intellectual, and no part of him can be turned aside while we deal with the remainder. It is possible to teach science in such ways that our students will come increasingly to value the good. It is possible to teach in such ways that our students will develop in emotional stature and in allegiances to the values and ethical systems that are deep in the mainstream of American democracy and the great religions that have given direction and substance to human events throughout history. Science for general education should be humane, not merely technical. It takes some doing to make it so, but good teachers are about the job. They know that the emotional and ethical well being of their students is in their hands in the same sense that their intellectual development is there. They know that their responsibility cannot be partial. Good teachers are not under the illusion that their students can be dissected and only the excised and throbbing intellects placed before them for their ministrations.

I am going to assume that we agree to this point. If there are those among us who insist that our proper job is but the purveyance of the verified truths of science or that science is to be thought of simply as the organized data that are the effluents of its philosophy and method, then there need to be other occasions on which we can discuss our differences. For I shall move immediately from this question of the fundamental nature of good science teaching in terms of broad

purposes to an analysis of some studies that may help us understand how good teachers are achieving the four dimensions of good science teaching which have been discussed. I shall have to report at times on studies that make comparisons between practices. In doing so I do not intend to be critical of what, for want of a better term, I shall call conventional practice. It would be more accurate to say that the comparisons made are between different kinds of practice. But this would lead to unnecessary ambiguity so I shall speak of "conventional" and "newer practices" while recognizing fully that good teachers have used the so-called "newer" practices from time immemorial. My only justification for calling them "newer" practices is that they represent a distinct trend in science teaching and are more typical of the work of good science teachers today than would have been true of the work of good science teachers a generation or more ago.

Let us look first at college preparation.

College Preparation

Sound preparation of youth for college is a function of the highest importance. Our country is suffering from a lack of scientists, engineers, technicians, and other scientific workers—particularly those in the creative areas. There is no question about the need. The question is rather what kinds of programs are best doing the job.

The studies that are pertinent to this question deal, in general, with the student backgounds, traits, and abilities which are predictive of college success. The results of these studies are expressed as predictive correlations. If students who take our high school science courses and make A's were always to achieve A's in the college equivalents of these courses, the predictive correlation would be 1.0. This would indicate that the taking of a high school physics course with high success would always produce the ability to take college physics with high success. If the high school science course resulted in grades which showed absolutely no relation to the grades students later receive in college, the correlation would be 0.0.

High school grades in specific subjects have a questionable validity when used for predicting college success, because the basis for such grades varies from teacher to teacher and from year to year.

A more accurate basis for determining the predictive value of high school courses is the results of standardized achievement tests which determine certain results of high school teaching.

Other factors have also been considered in the predictive studies. Aptitude, average high school marks, measured intelligence, and the taking of specific courses and patterns of courses all have been studied. These studies have clearly shown that success in college can best be

predicted on the basis of measured intelligence coupled with reading comprehension and average high school marks (which reflect the complex of attitudes and skills that might be epitomized as self-responsibility and study ability). Scores on achievement tests in specific subjects, on the other hand, provide the lowest predictive correlations. The following data support these assertions.

Kinney (1), Segel (2), and Durflinger (3) have found median correlations between measured intelligence and college academic success of .44, .44, and .52, respectively. These studies prove the obvious: that intelligent students tend to do better in college than less intelligent students. Although these correlations are quite low we can start with the assumption that, other things being equal, the more intelligent students will do better in college than the less intelligent students.

Now, let us suppose that we neglect this intellectual factor, as such, for awhile and assume that students have had our courses both in sciences and other academic subjects. Let us give them achievement tests such as the Cooperative tests in these fields. Let us examine the records our students make in college and determine whether or not their results on our achievement tests are good indexes of college success. Many such studies have been conducted. Segel (4) grouped several of these and secured a median correlation of .545 between general achievement tests (testing knowledge and usage of all the major subject disciplines) and college scholarship. This means that a battery of achievement tests can be given to a student and a slightly better prediction of his likelihood of succeeding in college can be secured, on the average, than could be secured by the use of intelligence tests. But, again, the correlation is quite low for accurate prediction. Surprisingly low, in fact. For achievement tests cannot exclude the operation of the intelligence factor, yet the correlations are but slightly higher than those obtained when intelligence, alone, is plotted against college success.

It is interesting, therefore, that aptitude tests are found to be quite as reliable as the far more time consuming achievement tests in predicting college success. The studies of Crawford and Burnham (5) reported in the Yale University publication, *Forecasting College Achievement*, support this as true. Now note the implications of this fact. The student who demonstrates an aptitude for the study of college subjects, including science, without reference to learned facts and principles as tested in achievement tests, can be predicted to succeed in college just as accurately as can the student who has taken these courses and succeeds well on tests designed to measure learned achievement. In effect, then, it would appear that intelligence

and the aptitude for academic work is the really significant factor that is being tested even in the achievement tests.

Now, let us narrow our sights a bit and focus directly on the science courses and their apparent relation to college success. A most revealing study is that reported by Kronenberg (8). He matched students at the General College of the University of Minnesota who were in special status because they had not taken certain subjects ordinarily required for admission, with other students of equal ability who had taken these courses in high school. He found that there was no significant difference in the college scholarship of the two groups.

Of course the most comprehensive study on this point was the well known "Eight Year Study," of which I shall have more to say in another connection. This study showed that specific subject-matter patterns and types of high school preparatory courses are not essential for academic success of students in college.

Let us focus even more sharply. To what degree is the ability demonstrated by a student in a conventional chemistry, biology, or physics class in high school an indication of the ability that he will later show in the college equivalent of that same course? (Clearly it should be somewhat indicative if for no other reason than that the highly intelligent student will tend to do well in the high school course and, as we have seen, intelligence correlates positively with college success.)

There are several studies which show, in general, that the average high school mark of a student in all of his studies correlates higher with his success in such a single college course as physics, chemistry, or in the biological sciences, than does the student's mark in that particular course in high school. Both the studies brought together by Jones (9) and the study of Pressey (10) report on this fact.

Now let me deal with aptitude tests in the specific fields of chemistry and physics. An aptitude test is not designed to determine the results of instruction. It does not determine what a student knows in a subject field. It determines with what facility a student can attack situations, problems, and learnings in a field. Such tests of specific attitudes in both chemistry and physics have disclosed correlations of .51 with college success in these same subjects. Segel's (11) bulletin reports on these studies. Apparently such tests mean more in predicting how well a student will do in a college course in physics or chemistry than tests given after a high school course in which an attempt is made to determine what a student learned. For such specific achievement tests correlate only .32 in both chemistry and physics with college success in the same subjects.

Note the interesting hypothesis that this provides us. As apti-

tude—the facility and ability with which a student can attack problems, situations, and learnings in these fields—appears to be more indicative of college success in these subjects than do learnings or achievement of knowledge in the subjects, it may be that more attention paid in high school science courses to the methodology of problem solving, critical analysis of the literature, and so forth, will produce students of greater promise than our conventional attempt to cover the fields of content. For we typically do so with such speed that the critical and reflective thought processes are never allowed opportunity of development. This, at least, is my hypothesis. It is one that influences the teaching procedures of many good teachers. And I think that it is a logical one supported by the foregoing data.

Can we test the hypothesis? It has been tested, in part, both directly and indirectly. Let me deal with the indirect test, first.

The highest correlations that have been found are those that result when general college scholarship has been measured against the combination of: (a) average high school marks, (b) results of intelligence tests, and (c) a test of English usage and reading comprehension. Edds and McCall (12) found a multiple correlation of .81 when this was done. Douglass (13) found approximately the same results from a similar multiple correlation.

What is the significance of this, and how does it indirectly test my hypothesis? Apparently the student will tend to achieve well in college (including college science courses) who, in general, has demonstrated that he knows how to study and to get along well in academic work as exemplified by good average high school marks (and it should be reiterated that what specific subjects are taken seems to be of little consequence); who has a high intelligence; and who can demonstrate that he can profit from study of printed materials which he will be obliged to peruse once he gets to college. Such a student, if he has drive and has an appetite for science, is almost certain to do well in college work in general and in science work in particular. Perhaps our chief job, so far as college preparation is concerned, is to stimulate and challenge our students so that they develop a strong interest in science; to demand that they take self-responsibility for tackling problems on their maturity level and treating them to successful conclusion; and to help them learn better how to use and profit from reference materials of various sorts. Good teachers go out of their way to locate students of promise. They give them special encouragement and assistance in learning as much science as they can while they are still in high school. Above all they challenge them to work reflectively and critically.

We need the scientists that such students are likely to become. They cannot be found by chance or hunch alone. They cannot be

helped by being placed in a routine physics, chemistry, general science, or biology class and left to loaf their way to boredom and distaste for science. They must be challenged, inspired, and encouraged toward rigorous, creative, and experimental work while still in high school. And if we can locate them and start them on their way in the elementary school, so much the better. It is possible to do so. But to do it requires informed, insightful, and willing teachers. Good teachers are taking the time and trouble to do it.

But how about a more direct testing of the hypothesis? In all parts of the country may be found science teachers who have utilized the findings of modern psychology and curriculum research and who have modified their programs in the directions I have indicated. Many of you are such teachers. Some of these teachers have followed up their graduates, and know what they have done, academically speaking, in college. Such students have typically done well in college. The data concerning them are rather fugitive and would require more consideration of delimiting conditions than my time affords. Let me, therefore, call your attention to the findings of the Eight Year Study which is the most comprehensive and carefully designed study of the type. Recall that the cooperating schools were released from the usual requirements of college preparation and that they varied in their experimental departures from a very small degree to a significant degree. Recall, also, that the general trend in the experimental schools was in the direction of programs, including science, in which students and teachers shared the job of determining the problems and issues to study, the ways of studying them, and the handling of the data secured. The most experimental science classes could be epitomized as problem centered, group planned and executed, and as classes that did not worry about precise subject matter lines, coverage of content, or constant achievement or mastery for all. They were classes, too, in which considerable reference work, experimentation on real problems, and contacts with the community were common. They were classes in which a great deal of group discussion was carried out and in which group- and self-discipline and responsibility were emphasized and imposed discipline was greatly lessened.

Recall, also, that when the students from the experimental schools went to college they were each separately matched with another student from a conventional school on the basis of aptitude, major field of study, sex, age, socio-economic status, and type and size of high school.

What were the results? Students from the experimental schools received higher grade averages in every science subject. As a matter of fact, except for foreign languages, they did better in every subject

than did their comparees from the conventional schools. They achieved more academic honors; more non-academic honors; were more commonly judged to be self-directive; were more informed about current affairs; were more commonly participating in all of the art forms. When the students from the six *most* experimental schools were compared with their peers from the conventional schools the superiority of the former was even more clear (14).

Why do the students from the kind of courses I have described do better in college than students of equal intelligence and similar backgrounds who were taught in more conventional courses? I do not know, but I would like to suggest some hypotheses. First, of course, they may have had better teachers who might have produced comparable results in conventional courses. This is rather difficult to entertain seriously because of the nature of the matching process that was used. Secondly, it may be that the very efforts of the experimental schools might have been a factor motivating toward better teaching and learning. This possibility cannot be ignored. But I think that there are other hypotheses worth exploring. Let me expand on one that I think merits your consideration.

College science is highly repetitious of conventional high school science. Spend a few hours sometime comparing your physics or chemistry textbook with its college equivalent. You may be surprised at the close similarity you will find. The college text will usually cover almost precisely the same material, in almost precisely the same order of areas, and with almost precisely the same general treatment. It will be somewhat more quantitatively involved and that is about the only substantive difference.

Koos (15) made a study of this. He found that the same relative amount of space was given to each topic by the high school books and the college books of chemistry and their manuals. He discovered that 100% of the content of a single high school chemistry manual was contained in one or another of the two college manuals. He concluded that a student who takes high school chemistry and then takes general inorganic chemistry in college repeats almost all of the high school course. Comparable results may be expected if the study were repeated for physics.

The blame for this redundancy should not, of course, be left entirely at the door of the high school teacher. Too few college teachers of science bother to determine how much their students already know at the beginning of their courses. Some do, of course, and urge qualified students to proficiency out of beginning courses. This is excellent. But the most able students are often forced into boring average grooves in beginning college science courses. This has been

well shown by Jones (16) in his interesting report in the University of Buffalo studies.

I think that good science teachers do not assume that taking such work in high school physics or chemistry will necessarily give the student ability to repeat the same work in college with high success. For such an assumption ignores the nature of learning and the fact that the sharp edge has been taken off by the time the learner is forced through the same mold the second time. Boredom, if nothing else, will often cause the student to neglect his studies the second time he is run through the mill. The brighter and more creative-minded the student, the more this is apt to be true. And when a student has been inflicted with repeated, superficial coverage through several years of general science, then physics, chemistry, and biology, and then the same old coverage in college he surely has had a surfeit of so-called science in his time. I earlier gave you statistical evidence suggesting that such conventional courses do not, in fact, produce good results in college on the basis of predictive correlations. I have given you a limited body of data that suggests that newer programs that emphasize critical analysis, intensive investigation, and a problem approach appear to produce somewhat better results than conventional text-paced programs that emphasize coverage.

Good teachers do not underestimate their students. They know that young people want to learn; they want to think; they want to find out and to experiment. The fact that they don't all want to study exactly the same things from the same textbook, at the same exact time, and in the same way, doesn't change the case at all. And the materials that are usually presented in the textbooks are surely of no greater importance than the power of analysis, ability in critical readership, functional understandings, and critical thinking that good teachers try to develop by breaking themselves away from this imagined responsibility to cover the field as presented by textbooks. I am not objecting to textbooks. They are basic tools of inestimable importance. But good teachers also use a wide variety of references and are not bound to a text. Let me turn, now, to the question of how good teachers teach for the retention and critical use of facts and principles of science.

Retention and the Critical Use of Knowledge

If we teach about a digestive enzyme, Avogado's hypothesis, or for skill in balancing an equation, presumably it is because we want the student to retain the knowledge or skill somewhat longer than required to pass an examination on the course. If a student forgets a large percentage of the facts he has "learned," if he cannot employ

principles, or if his skills rust within a short time, we can question whether the taxpayer and the student are getting a sound return from their financial and time investment in the science teacher.

Any science teacher can do his own informal investigation of retention by a process of asking single science questions to people he meets out of school. Any adult group, or group of students, who have been away from a science course for six months or more will be fair game. The results will be found most discouraging to the science teacher who has assumed that conventional science teaching that emphasized only facts has "taken."

There have been a number of formal investigations of the question of retention. Among the University of Minnesota studies was one conducted in 1930 by Johnson (20). He found a very poor retention of knowledge as indicated in ability to succeed in achievement tests in botany. The loss of retention after only three months as determined by achievement tests was 43.4%. Can we not properly question the value of teaching heavily for facts, to the virtual exclusion of other proper goals, when we find that those facts apparently learned as tested upon completion of the courses are over forty per cent forgotten in only three months?

Powers (21), who did the prototype study on retention in 1924 (with similar results) summarized the data on retention in the 1950 edition of the *Encyclopedia of Educational Research*. He concluded, relative to this matter of learning and retaining science information, that an all over-judgment, based on many studies, must hold that students in the physical sciences are not learning their subject matter well enough to use it on examinations. As this—the taking of examinations—is a skill that is developed by schools, one must expect that the low retention as exemplified on examinations represents an even lower retention of knowledge that would function in non-academic situations.

Long ago Henry Adams pointed out that "Nothing in education is so astounding as the amount of ignorance it accumulates in the form of inert facts." I don't think that any of us are interested in producing walking encyclopedias of factual information that is not used. But this is not to say that we are uninterested in having our students know, and know well, functional facts and principles. Indeed, it is because of the data we have that indicate the failure of much teaching in the past to develop substantial and usable knowledge of the facts and principles of science that good teachers have questioned many aspects of conventional practice. We all want our students to become well-informed, to use that knowledge wisely, and to continue to learn long after they have completed their formal education. How are good teachers achieving these aims? Let me

report a single study that shows—in my opinion—what good teachers are doing and the results that might be forthcoming from such general procedures. The study gives us interesting information not only on the retention of factual material but on an important aspect of critical thinking—the interpretation of data. The study was a comparison of two types of teaching and I shall leave to you the decision as to which represents the better science teaching.

Weisman (34) compared the relative effectiveness of these two general methods of teaching in developing the ability to interpret data. Six experimental and six control classes in tenth-grade biology participated in this study for a period of one academic year. The experimental classes utilized the problem approach and emphasis was placed upon group selection and attack on real problems. The work revolved around student interests and needs and basic aspects of living and functioning. As the problems were student determined it was necessary to secure and utilize a wide range of reference material. The problems grew out of the interests, concerns, and experiences of the students. The control classes were taught by "equally good teachers using their customary methods within the conventional organization of the biology course." Procedures were employed to equate the experimental and control groups on pertinent bases.

It was found that the students in the experimental groups achieved reliably greater gains in the ability to interpret data then did the students in the control groups. *They also made significantly greater gains in learning facts and principles of biology* as measured by the Cooperative Biology Test. One year after the period of instruction the students in the experimental groups had retained their superiority over the students in the control groups *both in their ability to interpret data and in knowledge of facts and principles*.

Weisman had emphasized the recognition of assumptions, proper qualification of conclusions, cautious use of predictions, and care in drawing reasonable conclusions and in applying them to new situations, rather than memorization of facts and principles. In a sense the study simply shows that a good teacher can develop these skills if he gives time to them.

But the really interesting thing about Weisman's study is that the general techniques employed in the experimental classes developed not only a higher ability in the interpretation of data but also a higher and more durable grasp of the facts and principles of the science as determined by standardized examinations. There are a number of studies, in fact, which show that techniques of teaching science which involve the cooperative participation of students and experience in the techniques of critical thinking on real problems are more effective than textbook dominated methods in achieving both

of these desirable outcomes. Such results are to be expected on logical grounds and research results generally show that the expected occurs.

To this point I have discussed the evidence which relates in some measure to how good teachers prepare students for college, develop a durable grasp of facts and principles, and help them to gain increased power in critical thinking. I could give you additional data, but I prefer to utilize the remainder of my time in discussing a few principles of learning that seem to me to most clearly disclose how good teachers achieve the three goals already discussed, and, in addition, achieve the vastly important aim of developing emotional and ethical maturity in their students. In doing so, I shall allude briefly to a number of studies that support my analysis.

Good Science Teaching and the Nature of Learning

It is my firm belief that outstanding teachers of science have always accepted at least four principles of learning as of cardinal importance. In many cases they have doubtless accepted these principles in an intuitive sense rather than from the basis of scholarship leading to an explicit recognition of them. But these principles, in my opinion, may be seen to be operating consistently in the classrooms of teachers who are really outstanding. And I think that you will agree that these principles underlie the kinds of good teaching the results of which have already been discussed.

First, good teachers know that all learning is purposive. The degree to which an individual student finds a purpose in educational activities is the degree to which real, as against verbalistic, learnings are possible. Let me explore the implications of this for good teaching. We must consider carefully whether the experiences we provide for our students are seen, by them as individuals, as purposive—as important—learnings. We should not be fooled by the fact that our students often can, and do, develop the ability to respond successfully to paper and pencil tests, into believing that this necessarily represents real learnings. For if the student's only purpose in learning certain facts or principles is to develop the verbalistic skill necessary to succeed in a formal, objective test on the course he may develop precisely these abilities and little more. If the student is brought to understand the importance and value to him of proposed science learnings (which can be done, of course, only if these actually do have importance and value to him as an individual), then he will have an insight into them and a goal for learning that will produce understandings, attitudes, and skills that meet his purposes and help him to achieve his goals.

This does not imply that the teacher must follow the whims and casual interests of his students and ignore areas of learning that he

knows to be of real worth to them. Good teachers never make this mistake. But they do recognize that the teacher will be unsuccessful in teaching the most highly important learnings if the learner does not accept them emotionally and intellectually as of importance and value to him. The good teacher knows, therefore, that his first job is to challenge the thinking of his students to the point that they share, with him, an insight into the intrinsic worth of the learnings. Extrinsic motivations such as threats and grade awards without a doubt produce a species of learning. But the student may then work merely to achieve the extrinsic awards or to avoid the penalties implied in the threats and, once these hurdles are jumped, his "learnings" recede to the vanishing point.

It is for this reason, among others, that good teachers spend a considerable amount of time planning units of work and their execution with their students in courses designed for general education. Such planning periods give them an opportunity to learn of their students' backgrounds, interests, and present insights. They give the teacher the opportunity of adjusting the organization and development of the proposed unit so as to capitalize on his students' interests and to help them see the meaning of the area under consideration to their lives and concerns. Unless the teacher succeeds in this process of intrinsic motivation he might as well move on to other areas. For no more extravagant waste of teaching time can be found than that of teachers attempting "to get across" material for which students see no value. I am not protesting that technical, logically organized courses are not desirable. Technical courses, elected by students who desire technical training, provide this intrinsic motivation for such students to the degree that the content is, in truth, of technical value. But to offer such logically organized content—taken as it is from technical disciplines—to high school students of diverse interests, needs, and purposes is psychologically indefensible and educationally unprofitable.

A second principle that good teachers recognize in their teaching is that learning is complex and that the learner learns many things at one time, and learns as a complete organism.

For purposes of analysis it is sometimes useful to break down educational objectives into knowledge, understandings, attitudes, and skills. But a student can never learn a fact, a concept, a principle, or a skill without certain concomitant learnings and changes in his total personality. While students are learning to balance equations in chemistry they are learning many other things at the same time. Just what they learn will depend upon their total motivation in the situation. They may learn to cheat, to hate chemistry, to fear and avoid competition, to find the pride of good workmanship, or to com-

mand the respect of their peers. Good teachers provide wholesome learning situations so that the entire range of their objectives toward developing strong human personalities may be reached even through the apparently simple process of instruction in balancing equations.

Note my point. A teacher does not have the choice of teaching this relatively simple skill with no concomitants, or of teaching for a pattern of desirable learnings. For concomitant learnings of profit or of harm will inevitably proceed. He can only choose to provide the total situation most conducive to the development of wholesome and effective personalities or to ignore these to his students' hurt. It the teacher is interested in developing democratic personalities and increased skills in cooperative group processes he will provide the setting for this development. He will not be an autocrat in the classroom and expect that his demands as an arbitrary authority will leave unaffected the aggressiveness of his students or their tendencies toward irresponsibility when imposed authority is absent.

For concomitant learnings always occur. Good teachers are particularly careful to avoid practices that create arbitrary hurdles of accomplishments for all of their students. We would not countenance the practice of requiring all students to jump hurdles of an arbitrary height in the athletic field regardless of their physical prowess. For it is easy to observe the range in physical types and to recognize the danger to the bodies of children with incipient hernias and cardiac involvements. In sound programs of physical education, we work for the optimum development of each child and we provide physical examinations to determine reasonable goals for individual achievement.

Our common practice in academic work is sometimes less sensible. We set arbitrary standards and achievement hurdles and ask all to jump on a timed basis. We then count as failures those who have not jumped the hurdles and as successes those who have jumped them well. The fact that many who jumped them could have jumped far higher had we challenged them to work more nearly at their optimum is of concern to good teachers. Moreover, they are concerned about the results of requiring the less gifted to do what they can toward jumping these hurdles and then marking them on a continuum so that they can see how poorly they have done when compared with the more gifted. The old saw that this prepares students for the real world of competition is logically absurd and ignores the nature of real competition. For such school competition is for grades and symbols, not for real accomplishment. It degenerates very easily into pathological envy and frustration that creates a tendency on the part of the student to avoid competition and to employ anti-social detour behaviors to make up for his growing personality lacks. Con-

tinued failure produces work of decreasing quality as has been reported in a minor dimension by Sears (22). Any practicing psychiatrist can add to Sears' data from his own practice. The famous "Studies in Deceit" of Hartshorne and May (23) have clearly shown the deceptive behavior indulged in by students who were unable to attain arbitrarily set school goals by direct means. Kvaraceus (24) and Sandin (25) have also studied this phenomenon. The studies of Lewin (26) and of Dollard (27) and their colleagues add to the data. These studies show the effects of teacher dominated classroom procedures in producing frustrations and their many concomitants. Failure students are often unhappy, negatively aggressive, and delinquent. They will cheat, rationalize, and often quit trying altogether if the competition is too intense. We need people who are psychologically secure and who are informed. Neither security nor optimum knowledge can result from a practice based on arbitrary standards of accomplishment for all. Good teachers work for the optimum development of each child. Many of them have gotten away from our common anachronistic grading system.

The good teacher knows that any unit of instruction and any single class hour of instruction is pregnant with possibilities for the development of sounder personalities of higher stature. Curiosity, drive, responsibility, effective communication skills, critical mindedness, good citizenship, feelings of belonging and being liked, personal security—all of these are affected positively or negatively every instructional hour of the day for better or for worse. Good teachers know that these are often negatively affected. They know, too, that they can be positively affected. The studies of Wrightstone (28), Morgan and Ojemann (29), Jersild (30), Blair and Goodson (31), Kilgore (32), Arnold (33), and Weisman (34), among many others disclose the kind of democratic classroom and environment that is conducive to the positive development of these strengths. We don't need to guess. A teacher can ignore his responsibility to his students and to society and "teach his science." But good teachers know that his science will be less well taught, less well learned, and his higher function as a representative of both democracy and science to young people will have been subverted.

A third principle of learning that is recognized to be of great importance by outstanding science teachers is this: Principles (generalizations) cannot be developed, except as empty verbalizations, other than through the inductive process of studying concrete situations out of which generalized insights may emerge. A generalization is, by definition, that which one generalizes out of concrete experiences. Yet generalizations are often taught as verbalisms. They are often taught as if they were facts.

There is a great distinction between a generalized insight and the ability to write or state the words that happen to express the insight that scientists have developed concerning certain relationships. Many students have learned to say "A body immersed in a fluid is buoyed up by a force equal to the weight of the fluid displaced," or, "E equals IR" and have not the foggiest notion of the relationships that are expressed by these statements. This can easily be demonstrated by comparing students' responses to paper and pencil tests with their ability when faced with a real life situation in which these relationships obtain. It is of no ultimate importance that students learn to state a principle in precise fashion. The important thing is that a student understands the principle that is operating—that is, that he understands the relationships obtaining. Once he has developed such an understanding he can make out his own statement with sufficient precision to suffice for all ordinary purposes. And he will retain even the ability to state the principle much longer than the student who has developed only the verbalism, because the former knows what it means. It is not a nonsense syllable to the student who really understands.

Good teachers know that a generalization is not something written on paper. It is something that happens inside a learner. As a generalization is something that happens internally and not a memoritor learning to be stated trippingly from the tongue, it probably cannot be learned in a functional sense except through the process of studying real problem situations or phenomena in which the principle operates. The laws and principles of science were developed precisely through such an inductive process. Although deductive experiences are also important, the student can only really develop insights by the same inductive process used by the scientists who first enunciated them.

The fourth, and last, principle of learning that I want to discuss is this. Learnings will transfer to the extent that the learner sees the possibility of transfer to other situations where the learning is applicable; to the extent that he has generalized from his learnings so that he understands the principles involved; and to the extent that he is given practice in making transfer of these generalized insights into new situations.

Science, as a field, does not represent interest in the particular. This is to say that science is interested in those generic truths which can be stated as principles or laws of sufficient general scope that they can be applied, with better bases of control and prediction, to new situations. There would be little profit in learning about gravitation if every object had its own unique attractive force directed to as many different objects each with its own unique attractive force. The value

of science is that it is possible to elicit from concrete specific cases generalized principles that will apply with equal validity and accuracy to a wide universe of other specifics.

This being true, we have no legitimate interest in our students learning a conglomeration of discrete facts that, being discrete, will not function in the great range of activities and affairs of their lives. Public education is provided at the expense of patrons and other taxpayers so that children will mature into effective persons and citizens capable of controlling their affairs and those of a democratic society with higher power and efficiency. This means that the learnings of highest worth are those that have high transfer value to the student's daily life and to his affairs as a democratic citizen. This does not ignore our high responsibility to the gifted student to start him well on the road to professional scientific competence. It does suggest that we utilize the criteria of democratic and scientific values, of personal needs, and of societal needs for the determining of the content and experiences desirable for our students. And good teachers quite typically use these criteria in determining their programs.

The evidence is distinct and emphatic that the ability of an individual to transfer a learning to other situations requires that the learner be helped to see the possibilities of such transfer. This does not mean that the teacher is under the necessity of revealing to his students the entire range of possible applications. This would be patently impossible and, of course, totally unnecessary. What good teachers do, to improve the chances that the learning will function in the individual's life, is to help him to see some applications of the learning to things that he is familiar with and to provide additional novel situations to give the student opportunity to make the transfer "under his own steam." If the student cannot do this it is evidence that real learning has not occurred and that further teaching is required.

It can hardly be held sufficient that we provide the student with an insight into the transferability of a technical learning from one technical context to another equally technical area completely divorced from the student's life. Except, let me state emphatically, as competent students in elective courses desire to engage in rigorous work of such technical nature. This latter we should encourage. But, in general, our students should be helped to understand those principles and concepts that are valid and relevant to *their* affairs and to see *how* they are relevant and will affect their lives for the better. If a student can be brought to see such possibilities in what he is learning, and if he is given an opportunity to practice such applications, the teacher can feel confident that he is making science a living part of the student's life. If we cannot do this and demonstrate that it

is being done, all of the high scores on the standardized instruments in the world will not change the fact that we have largely failed as science teachers in a democracy.

A Summary

Let me summarize the position that I have taken regarding how good teachers teach science. I have assumed that good science teaching consists in the optimum development of each child in our classes in usable and functional knowledge, in understandings that will operate in his personal and public life, in skills of learning, thinking, and doing that will make him a lifetime student of increasing stature as time goes on. I have assumed that good science teaching prepares capable students for effective college work. I have assumed that good science teaching consists, in part, in helping our students develop an increasingly clear ethical and moral sense that is rooted in the basic concepts of democracy and the Judaic-Christian ethic. I have assumed that science itself can be a powerful force in developing moral stature, for the morality of consequences that is the core of the naturalistic viewpoint of science provides full support to the concepts of democracy and our religious ethic that freedom, self-responsibility, justice, and the moral equivalence of each individual must be jealously guarded.

Although I have not dealt directly with every aspect of these assumptions, I have attempted to consider the evidence, in research, that discloses what good teachers do about these things—evidence on the newer practices that appear to be more conducive of the results we are interested in. I have, finally, suggested four important principles of learning that are commonly followed by good teachers and which have theoretical sanction and experimental support today. Although I must admit that most of our experimental data are of presumptive, rather than of conclusive validity, I urge for your consideration that we have a sufficient basis in both fact and theory upon which to improve our science teaching in America today.

Good teachers constantly work to improve their teaching. That's why they are good.

References Cited

1. Kinney, L. B., "A Summary of the Literature on the Use of Intelligence Tests in Colleges and Universities." U. of Minn. Comm. on Educ. Research, 1932 (Mimeo.).
2. Segel, David, *Prediction of College Success*. U.S.O.E. Bull. No. 15, 1934.
3. Durflinger, G. W., "The Prediction of College Success: A Summary of Recent Findings." *Amer. Assn. Col. Reg. J.* 19: 68–78, 1943.
4. Segel, David, *op. cit.*

5. Crawford, A. B. and Burnham, P. S., *Forecasting College Achievement.* Part I, Yale U. Press, 1946, 291 p.
6. Segel, *op. cit.*
7. Douglass, H. R. "The Relation of High School Preparation and Certain Other Factors to Academic Success at the University of Oregon." Univ. of Oregon Publs., Vol. 3, No. 1, 1931.
8. Kronenberg, Henry, "Validity of College Entrance Requirements." Studies in Articulation. Univ. of Minn. Comm. on Educ. Research, 1937, p. 61–83.
9. Jones, E. S. (ed.) *Studies in Articulation of High School and College,* Univ. of Buffalo, 1934, 1936, 2 vols.
10. Pressey, S. L., "Credit by Examination; Present Use and Future Need," *J. Ed. Res.* 38: 596–605, 1945.
11. Segel, *op. cit.*
12. Edds, J. H. and McCall, W. M., "Predicting the Scholastic Success of College Freshmen." *J. Ed. Res.* 27: 127–30, 1933.
13. Douglass, H. R., *op. cit.*
14. Chamberlin and Chamberlin, *Did They Succeed in College.*
15. Koos, L. V., *The Junior College,* U. of Minn., Res. Publication Ed. Series, No. 5, 1924.
16. Jones, *op. cit.*
17. Learned, W. S. and Wood, B. D., "The Student and His Knowledge," Carnegie Foundation for the Advancement of Teaching, Bull. No. 29, 1938, 406 pp.
18. Hoff, Arthur G., "The Effect of the Study of High School Chemistry Upon Success in College Chemistry," *J. Ed. Res.* 40: 539–42, March, 1947.
19. Meyer, Martin, "A Case Study of College General Chemistry," *J. Chemical Educ.* 22: 325–27. July, 1945.
20. Johnson, P. O., *Curricular Problems in Science at the College Level,* U. of Minn. Press, 1930.
21. Powers, S. R., *A Diagnostic Study of the Subject Matter of High School Chemistry,* Contributions to Education, No. 149, Teachers College, 1924.
22. Sears, R. R., "Initiation of the Repression Sequence by Experienced Failure," *J. Exp. Psychol.* 20: 570–80, 1937.
23. Hartshorne, Hugh and May, M. A., *Studies in Deceit,* Macmillan, 1928, 2 vols.
24. Kvaraceus, W. C. "Delinquency—A By-product of the School?" *Sch. and Soc.* 59: 350–351, 1944.
25. Sandin, A. A., *Social and Emotional Adjustment of Regularly Promoted and Non-Promoted Pupils,* Col. U. 1944, 142 pp.
26. Lewin, Kurt, and others. *Authority and Frustration. Studies in Topological and Vector Psychology,* Vol. III, Univ. of Iowa Press, 1944, 308 pp.
27. Dollard, John, and others, *Frustration and Aggression,* Yale Univ. Press, 1939, 209 pp.
28. Wrightstone, J. W., "Evaluation of the Experiment with the Activity Program in the New York City Elementary Schools," *J. Ed. Res.* 38: 252–57, 1944.
29. Morgan, Mildred I. and Ojemann, R. H., "The Effect of a Learning Program Designed to Assist Youth in and Understanding of Behavior and its Development," *Child Develop.* 13: 181–94, 1942.
30. Jersild, A. T., and others, "An Evaluation of Aspects of the Activity Program in the New York City Public Elementary Schools," *J. Exp. Ed.* 8: 166–207, 1939.
31. Blair, Glenn M. and Goodson, Max, R., "Development of Scientific Thinking Through General Science," *Sch. Review* 47: 695–701, November, 1939.
32. Kilgore, Wm. A., *Identification of Ability to Apply Principles of Physics,*

Doctor's thesis, New York, T. C., Columbia U. No. 840, 1941, 34 pp.
33. ARNOLD, DWIGHT L., "Testing Ability to Use Data in the Fifth and Sixth Grade," *Ed. Res. Bull.* 17: 255–59, 278, December, 1938.
34. WEISMAN, LEAH L., *Some Factors Related to the Ability to Interpret Data in Biological Science,* Chicago U., 1946, 176 pp. Doctor's thesis.

NOTE ON TEACHING

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I want to discuss briefly what I would like to call the system. This system has all too wide application in our classes in elementary college mathematics. It consists of listening carefully to explanations given in class, taking perhaps a few notes, but copying in full from the blackboard any problems that may be solved there. No preparation is made outside of class until an hour test is announced. Then the notes are read more or less carefully, and an attempt is made to memorize the problems copied. This leads to strenuous cramming the night before the test. A student can coast along with the system and even pass the course with a low grade. If he has high aptitude, he may even obtain an average grade. A student may use the system without detection most readily in large classes. With such classes the instructor can not send the whole class, or even a large part of it, to work together at the blackboard while he oberves the efforts of individual students. Under these circumstances he may call for volunteers to solve problems at the board, and, of course, the user of the system does not volunteer. If the instructor chooses individuals, the turn of a particular student comes seldom. Thus the user of the system is not often discovered. The system is likely to flourish most when the instructor lectures and himself solves the problems asked about. At the end of the semester the performance of the class will have been poor. But the instructor may have a superior who scans per cents of failure. Hence the instructor fails as large a number as he can and at the same time avoids too bad an impression on his superior. Then a goodly proportion of the users of the system may pass. Of course, the evil effect of the system on the student is accumulative.

An efficient teacher will try to stop the use of the system. Experience seems to show that one effective means is the short quiz of from five to fifteen minutes given daily, or at least once a week. These quizzes, even with a large class, can often be marked and recorded in half an hour. A student who had failed analytic geometry was asked how he was progressing with its repetition. "Fine," he replied. "I have found a method for passing analytic geometry. It is get your lesson every day." His instructor was giving short daily quizzes.

TRICKS THAT CLICK*

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Much excellent material has been written about instructional methodology in the field of arithmetic—349 successful teaching techniques are contained in the *Chicago In Service Study of Arithmetic Teaching* alone! It would seem, then, that any more of the same would be as "carrying coals to Newcastle." The purpose of this article, therefore, is not only to share with you some step by step techniques which help present arithmetic concepts in a meaningful way, but to present, perhaps, a different approach to well known techniques, added and more careful steps to prevent so-called blocks to learning, simplification or omission of accepted steps which tend to "cloud the issue," and to suggest some practical visual aid materials with which to build up an arithmetic "library."

Circumference and Diameter

REQUIREMENTS

1. Materials.
   a. Two or three large circular objects such as a wastebasket. Marks on rim for measuring diameter.
   b. Non-elastic cord, scissors, tape measure.
   c. Two cardboard circles, not plane, diameters 7″, 14″.

2. Background.
   a. Vocabulary: circumference, diameter, radius, linear (line, long, distance to, distance around) measurement, compare.
   b. How to multiply and divide by a mixed number, by a decimal number.
3. Motivation.

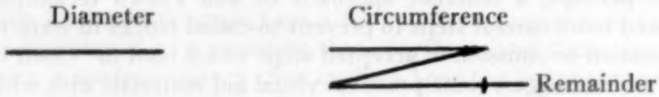
PRESENTATION

1. Encircle the object with cord as accurately as possible and cut cord. "This is the circumference. It is a line, the distance

* Presented at the Elementary School Program of the Central Association of Science and Mathematics Teachers, Chicago, November 27, 1954.

around the circle, and is measured in inches (linear units). Please hold this circumference while the diameter is measured."

2. Measure the diameter with cord and cut. "This is the diameter. It, too, is a line, the longest distance across the circle, measured in inches (linear units). Please hold up the circumference and diameter so that we may compare them."
3. Compare. "Which is smaller? Larger? Is the circumference twice as long as the diameter? Three times as long? Four times as long? Let's see."
4. Carefully compare the diameter with the circumference by folding the circumference into three sections each equal to the diameter and having a remainder.



"The circumference is a little more than three times as long as the diameter. It is three and a 'tail' times as long—three and a fraction times as long."

5. Repeat steps 1, 2, 3, 4, with other circular objects to generalize: The circumference of a circle is three and a fraction times as long as the diameter.
6. "Now let's find out about this 'tail,'' this fraction, that's always left over." Carefully compare the "tail" with the diameter of the circle to approximate $\frac{1}{7}$ by laying out the "tail" on the diameter seven times.

Repeat to generalize: The circumference of a circle is approximately $3\frac{1}{7}$ times as long as the diameter.

7. "Of what value is this knowledge? If the diameter is known, the circumference can be found by multiplying the diameter by $3\frac{1}{7}$. If the circumference is known, the diameter can be found by dividing the circumference by $3\frac{1}{7}$." (Symbols and formulas much later when concept is fixed). Note, from experiences of children, objects whose circumference only can be measured—growing giant trees—objects whose diameter is more easily measured—plates, records.
8. "Now let's try one. What is the approximate circumference of a circle whose diameter is 7 inches?" $3\frac{1}{7} \times 7'' = 22''$. Prove by measuring with tape the 7" cardboard circle. "Try this one. What is the approximate diameter of a circle whose circumfer-

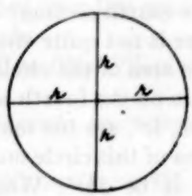
ence is 44 inches?" 44″ divided by $3\frac{1}{7}$ is 14″. Prove by measuring 14″ circle.

9. Practice, first using multiples of 7 or 22. *D*—28, 35, 42. *C*—66, 88, 132. Then increase difficulty in this order: Find *C* if *D* is 10′. Find *D* if *C* is 60″. Find *C* if *R* is 12′. Find *R* if *C* is 88″. Never proceed to any succeeding step until preceding step is fixed.
10. Explain that $3\frac{1}{7}$ is more accurately 3.14. For able groups or individuals an approximation of 3.14 can be reached by dividing *C* by *D*. Practice using 3.14.
11. Introduce symbols and formulas, always repeating, reviewing, stressing the basic concept—the circumference is $3\frac{1}{7}$ times as long as the diameter.

Area of Circles

REQUIREMENTS

1. Materials.
   a. Squares, 6″, 7″, 8″.
   b. A circle 10″ in diameter divided into 4 equal segments with 4 radii marked "*r*."



   c. Four 5″ squares, dimensions marked "*r*" and area indicated as r^2.
2. Background.
   a. Concept of area or surface—measured in square units.
   b. Understanding of how to find the area of a square. Formula $s^2 - s \times s$, 5×5 or 25 square units.
   c. Vocabulary: circumference, diameter, radius, radii, pi, unit of measure.
   d. How to multiply by a mixed number, by a decimal number.
3. Motivation.

PRESENTATION

1. "How is the area of this 6″ square found?" 6×6 or 36 square inches. "Rule (formula, symbol)? *A* is $s \times s$ or s^2." Repeat with 7 and 8 inch squares.

2. Develop slowly, carefully, step by step:
   a. A formula for finding the area of a square if the length of a side were represented by the letter "b" instead of the letter "s": A is $b \times b$ or b^2. Repeat, using several letters and winding up with $r \times r$ or r^2.
   b. A formula for finding the area of two equal squares if the length of a side were represented by the letter "m": $2m^2$ ($m \times m$ or m^2, then $2m^2$). Repeat, using 3, 4, 5 equal squares and various letters to represent the length of one side. Wind up with $4r^2$.
3. Show the four 5″ squares you have prepared. Review the formulas: A is $r \times r$ or r^2. A is 5×5 or 5^2 or 25 square inches. Area of two squares is $2r^2$, three squares is $3r^2$, four squares is $4r^2$.
4. Examine the 10″ circle. Note it is divided into four equal parts (segments)—radii have been marked "r." Measure radii. Each is 5″ long—same as length of side of squares.
5. Place, slowly, one at a time, three of the 5″ squares over three of the segments of the circle, stopping to say r^2, $2r^2$, $3r^2$. "We are trying to cover the area of our circle but notice that we have three corners sticking out beyond the rim of the circle! Do you think that these three corners might be enough to cover the area of the fourth section? You will have to take my word for it that there is not quite enough area in three squares to cover or equal the area of the circle, and so $3r^2$ is too small."
6. Put the fourth square on the fourth segment. "You can plainly see that four squares, $4r^2$, are too many. If $3r^2$ is too small and $4r^2$ is too big, the area of this circle must be somewhere between $3r^2$ and $4r^2$. Could it be $3\frac{1}{2}r^2$? Would someone volunteer a guess?" If not, the teacher must tell the class that it takes $3\frac{1}{7}r^2$ to find the area of a circle.
7. Find the area of the circle. The area of one square is r^2 or 5×5 or 25 square inches—the area of $3\frac{1}{7}$ squares is $3\frac{1}{7} \times 25$ square inches or $75\frac{4}{7}$ square inches, the area of the circle. Practice with other radii.
8. Write formula πr^2. Use it as in #7 above. Use 3.14.
9. Find area when diameter is given.

PER CENT—CONCEPT AND FIRST CASE
(*Meaning of Per Cent* is an excellent film)

REQUIREMENTS

1. Graph paper, rulers.
2. Background.
   a. An understanding of the meaning of fractions: $\frac{2}{3}$ means two

of the three equal parts of one, or two of a total of three equal "things." Practice in showing ⅔ of one, finding ⅔ of many things.

b. Ability to compare numbers: 3 is ¾ of 4, 7 is 7/100 of 100.
c. Ability to write and work with dollars and cents.
d. Understanding of place value, ability to read, write and work with decimals.
e. Vocabulary of fractions and decimals.

3. Motivation.

PRESENTATION

1. Recall experiences with per cent. Define per cent:
   a. By the hundred (centum).
   b. Part of a hundred.
   c. A given number of hundredths.
   d. A part, expressed as hundredths, of one (whole, thing). Stress.
   e. A part, expressed as hundredths, of more than one, of many things. Stress.
2. Per cent, from 1*d* above, is a part, expressed as hundredths, of one. Use graph paper to illustrate:
   a. One whole divided into 100 equal parts, each 1/100 or .01 or 1% of the whole.
   b. Five parts, 5/100 or .05 of 5% of the whole. Use many examples.
   c. One dollar as 100 cents, each cent 1/100 or .01 or 1% of the whole dollar.
   d. Four cents, 4/100 or .04 or 4% of the whole dollar. Use many examples.
3. Fix meaning and writing of per cents by comparing to money:
   a. Two cents is 2 of the 100 cents in a dollar: $2/100 or $.02.
   b. Two per cent is 2 of the 100 equal parts of anything: 2/100 or .02.
   c. Use many examples, and when need arises, the writing of difficult per cents such as 2½%, 200%, 3.5%, 150%, etc. can be simplified by comparing thus to money.
4. Per cent, from 1*e*, is also a part, expressed in hundredths, of more than one, of many equal things. From this, first case per cent problems, finding a per cent of a number, can easily be developed.
5. "Can we solve this problem?" Fifteen per cent of an audience of 300 people left early. How many people left early?
   a. "We have learned that per cent is a part, expressed as

hundredths, of one thing. We have shown many per cents of one whole on graph paper."

b. "We also know that per cent is a part, expressed in hundredths, of many equal things. We know how to find a fractional part of many equal things: $\frac{2}{3}$ of my 12 pencils is 8 pencils, $\frac{3}{5}$ of \$5.00 is \$3.00. Now we are ready to find a per cent of many equal things, and solve our problem.

6. Solution:
   a. Per cent is a part, expressed as hundredths, of something, less than all of it.
   b. Fifteen per cent is 15/100 of something, less than all of it.
   c. Fifteen per cent of 300 people is $15/100\times 300$ people or 45 people, less than the audience of 300.
   d. Fifteen per cent of 300 people is also $.15\times 300$ people or 45 people who left early.
7. Repeat and practice until finding a given per cent of something is fixed as multiplying the whole or total by the per cent written as a decimal and that the result will be less than the whole, a part of the whole. Per cents that can be written as fractions—equivalent parts of 100—can be developed when need arises.

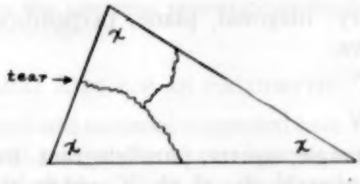
The Sum of the Angles of Any Triangle Is Equal to 180 Degrees

REQUIREMENTS

1. Material.
   a. Protractors.
   b. Cut out triangles of various kinds and sizes.
2. Background.
   a. Concepts angle, triangle.
   b. Familiarity with kinds of angles, right, acute, obtuse, straight.
   c. Unit of measure—degrees—and how to measure angles with protractor.
   d. Vocabulary: vertex, other words used above.
3. Motivation.

PRESENTATION

1. Mark plainly the three angles of a prepared triangle with x's near to the vertex of each.
2. Separate the angles by tearing, being careful not to destroy the angles.
3. Fit the angles together, vertexes meeting so as to form a



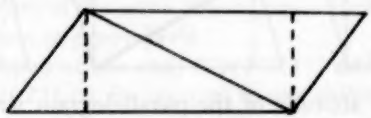
straight angle. Class notes that a straight angle, 180 degrees, is formed. Repeat with other triangles.

4. Prove by measuring size of each angle of a triangle and adding together to equal 180 degrees. Repeat to generalize: The sum of the angles, etc.
5. "If the sizes of two angles of a triangle are given, the third angle can be found by adding the number of degrees in the two given angles and subtracting the sum from 180 degrees." Practice finding angle 3.
6. "The size of only one angle of a right triangle need be given to find the size of the third angle, since a right triangle contains one right angle—90 degrees." Practice finding angle 3.
7. "Only one angle of an isosceles triangle need be given to find the third angle since an isosceles triangle contains two equal angles." Practice finding angle 3 when one of the equal angles is given; when angle not one of the equal angles is given.
8. "Each angle of an equilateral triangle measures 60 degrees since the three angles are equal and 180° divided by 3 equals 60 degrees."

Area of Triangle

REQUIREMENTS

1. Materials.
   a. A rectangle, a square, a parallelogram. Diagonals drawn. Atitude of parallelogram drawn at each end thus:



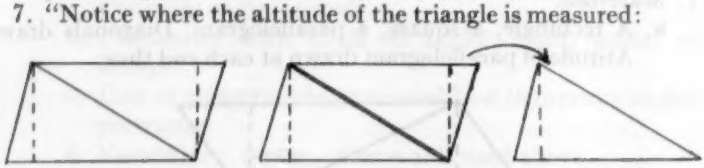
   b. Scissors, ruler.
2. Background.
   a. Concept area—measured in square units.
   b. Understanding of how to find areas of rectangles, squares, parallelograms. Formulas $1w$, $s \times s$ (s^2), ab.
   c. Concept triangle.

d. Vocabulary: diagonal, plane, perpendicular, other words used above.

3. Motivation.

PRESENTATION

1. Display rectangle, square, parallelogram. Review formula for finding area of each—lw, s^2, ab. "Could we also use the formula "*ab*" for finding the area of a rectangle? A square? Let us agree to use the formula "*ab*" for finding the area of these planes."
2. Cut the rectangle on the diagonal drawn, forming two equal triangles. "What has been formed? Are they equal in area?" Place one over the other to prove equality. "Has the altitude of the rectangle been changed by cutting? The base? What has been changed? The area, of course. In what way has it been changed? We have divided the area by two—the area of the triangle is only half as large as the area of the rectangle."
3. "We agreed to use the formula "*ab*" for finding the area of our rectangle. Could you suggest a formula for finding the area of this triangle which has the same altitude and base?—*ab* divided by two, $\frac{1}{2}ab$, $ab/2$."
4. "What is the area of this triangle if the base of the rectangle is 12″ and the altitude is 9″? 9×12 is 108 divided by 2 (or 9×6) is 54 square inches."
5. Repeat steps 2, 3, 4 with the square.
6. "Now let's see if a triangle formed when I cut this parallelogram diagonally is exactly half of the parallelogram." Cut, compare. "Has the length of the base been changed? The altitude? The area? Yes, the area of a triangle is $\frac{1}{2}$ the area of the parallelogram—*ab* divided by two, $\frac{1}{2}ab$, $ab/2$."
7. "Notice where the altitude of the triangle is measured:



Just as the altitude of the parallelogram was measured on a line perpendicular to the base, so the altitude of each triangle is measured on a line perpendicular to the base."
8. "The altitude of the parallelogram is 4″, its base is 8″, what is the area of triangle formed? $\frac{1}{2}$ of 4×8 (2×8 or 4×4) or 16 square inches."
9. Practice, using whole numbers first, then fractions and decimals.

The quotes used in the preceding presentations should be drawn from the children whenever advantageous.

Some Visual Aids for an Arithmetic "Library"

Much of the visual aid material suggested here can be made or collected by pupils and teacher, some can be constructed by interested fathers, or in school shops, others can be inexpensively made up at lumber yards, cabinet shops or tin-smiths. All will pay big dividends in time-saving, meaningful teaching, review, and as reminders that will prevent many careless or "forgetting" errors. A "Tools of Arithmetic" cabinet will house such materials where they are available to pupils and teacher alike—some materials can be permanently displayed.

1. A chart displaying a length of string or a tape measure to illustrate linear units of measure and labelled "*L, L, L*" for linear, line, long; a square of colored paper to illustrate square units of measure and labelled "*S, S*" for square, surface; a paper cube to illustrate cubic units of measure and labelled "*C, C, C*" for cubic, capacity, content. Other "key" words such as distance, length, width, perimeter, circumference; area, cover, paint, seed; volume, hold, fill, contain, can be added.
2. A square yard, divided into nine square feet and numbered, painted on the floor. A cardboard square foot divided into 144 square inches and numbered.
3. An inch, a foot, a yard, a rod, can also be painted on floor or blackboard.
4. A board foot cut out of lumber, dimensions and content labelled.
5. Boxes $6'' \times 4'' \times 3''$ and $4'' \times 4'' \times 4''$ and enough one inch wooden cubes to fill these, for teaching volumes of rectangular prisms and cubes.
6. Matching rectangular prisms and pyramids of tin to demonstrate that the volume of a pyramid is $\frac{1}{3}$ the volume of a rectangular prism of the same dimensions—$\frac{1}{3}lwh$. Matching cylinders and cones to prove $\frac{1}{3}\pi r^2h$.
7. A tin box (open at one end) $3'' \times 7'' \times 11''$ and a gallon measure to show that 231 cu. in. is equal to one gallon. A tin cubic foot to show that a cubic foot contains approximately $7\frac{1}{2}$ gallons.
8. Other charts (decorated with stick figures in appropriate action to make charts more arresting) showing:
   a. steps in finding area of a circle (as described in preceding techniques).
   b. reminders to avoid common errors such as, amount is the sum of the principal and the interest; dimensions must be

in the same unit of measure to find perimeter, area, volume; sale price is regular price minus discount; per 100—point off two places or cross off 2 zeros; add to find perimeter, multiply to find area of squares and rectangles.

c. per cents, equivalent fractions and decimals—if placed on display for ready reference much hard memorization is avoided.
d. common squares and roots.
e. reminders about placing the decimal point in adding, subtracting, multiplying, and dividing decimals.
f. lines, angles, triangles—kinds, names; solids, planes—kinds, names.
g. recognition keys for 3 cases of per cent.

Every teaching technique must, of course, be adapted to the needs, background and abilities of a particular group, therefore steps in the foregoing presentations may be simplified, elaborated or repeated to satisfy prevailing conditions. However, if the skills, vocabulary and understandings listed as "background" are sound, good audiovisual aids are employed, and provision made for individual differences, the use of the suggested teaching techniques should result in understanding, learning, and skill in "performance." Happy teaching!

FREE MATHEMATICS PAPER

The *University of Oklahoma Mathematics Letter* is a four page publication of interest to high school and beginning college students and teachers. Copies will be sent without charge to persons requesting them and enclosing a stamped self addressed envelope plus a $3'' \times 5''$ card giving their name and school address. Send all requests to Professor Richard V. Andree, Department of Mathematics, The University of Oklahoma, Norman, Oklahoma. You owe it to your students to send for this interesting free publication.

A REPORT ON BIOLOGY TEACHING

The Report of the Southeastern Conference on Biology Teaching held at the University of Florida, August 28 to September 6, has just been published as the January issue of *The American Biology Teacher*.

The 64 page report summarizes the recommendations of the 96 people in attendance on how to improve biology teaching in high schools and colleges and how state departments of education can assist in the development of strong biology programs, particularly in the Southeast.

The ten-day Conference was sponsored by the National Association of Biology Teachers in conjunction with the annual meeting of the American Institute of Biological Sciences on a grant from the National Science Foundation.

Single copies of the Report are available free from Dr. Richard L. Weaver, Co-Director, School of Natural Resources, University of Michigan, Ann Arbor, Michigan. Those interested in the National Association of Biology Teachers, its conference program, the various projects underway, or membership, should write to Paul Webster, Secretary, Bryan High School, Bryan, Ohio. Conference reports are being sent to all old members and new members.

NEW FOODS FOR THE FUTURE*

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"Today, and every day, 10,501 people will be born in the United States and 4,074 will die. In addition, 720 people will migrate into the United States and 85 will leave. The net population gain today is 7,062 per day."

These are the words of Dr. Vergil D. Reed (1) in his discussion of the growth of America in a recent issue of a marketing magazine. He then asks—"Is your business getting ready to meet the challenge of 21½ million more consumers by 1960? By 1975 the population of the United States is estimated to be 193,000,000." We will have added the equivalent of 3 more Canadas to our population. And that is considering the United States only. China alone is estimated to have a population now of 600 million and, of course, it is still growing. In the case of the United States, the population gain of 7,000 people per day means we are adding to our population the equivalent of a Joliet, Illinois, Rock Island, Illinois, or Poughkeepsie, New York, every week. This tremendous growth of world population is creating many problems due to population pressure, not the least of which is the feeding of rapidly expanding populations with a diet that will provide the necessary proteins for a reasonably balanced diet.

Much of the world's population is already suffering a deficiency in essential food elements. The situation will be worsened because even now it is stated that there is not sufficient acreage in the world to provide meats for a high protein diet for the existing population. What will the situation be 50 or 100 years hence when world population will be greater than it is today?

New and efficient sources of food proteins must be developed and in this direction considerable research has been done in developing the growth of the green algae which exist so profusely in the relatively shallow waters of our lakes and oceans. I shall enumerate a few interesting examples of what has been done in this direction.

The algae comprise that large group of plants which are commonly known as phytoplankton (the free-floating microscopic plants of lakes and oceans), the pond scums and pond silks, and the seaweeds. The seaweeds are not newcomers in the field of nutrition. They have long been harvested and used both as livestock feed and fertilizer and as food for humans (2). Although their use as food is uncommon in America and Europe today, the seaweeds are still widely used in

* A paper presented at the Junior College Group Meeting at the Central Association of Science and Mathematics Teachers Convention, Saturday, November 27, 1954.

Hawaii and the Orient. And the use of certain seaweeds may soon be widespread for a new industry has arisen in Canada primarily for the harvesting and processing of one of the seaweeds which grows profusely along the Atlantic coast. This processed seaweed will be used for human consumption. It is a storehouse of minerals and is higher in protein content than whole wheat flour (3).

However, the use of seaweeds involves problems of distribution to inland users. What is needed is a crop plant that can be grown and harvested near the source of consumption. It is also necessary to have a crop which is less expensive to produce and which will yield more nutritive substances per ton than the usual land crops like wheat and corn. This new crop plant may be the unicellular green alga, *Chlorella*. Culturing *Chlorella* on a large scale involves complicated engineering problems and the first attempt to solve these problems was made at the Stanford Research Institute during the years 1948–1950. Other tests have been made at the University of Tokyo, Japan, the University of Texas, in Israel, England, the Netherlands, Germany, and Venezuela (4). In the United States, the first pilot plant was constructed by Arthur D. Little, Inc. Through these efforts it has been found that growing *Chlorella* on a large scale is feasible. It has been estimated that at the present time a yield of about 17 tons, dry weight, per acre per year may be expected. Estimates for the future are yields of 40 tons of dry weight per acre per year. This will mean yields of 20 tons of protein and 3 tons of fat per acre.

Why is *Chlorella* of such interest in this new development of food?

First, as a green plant, it is able to convert inorganic compounds into usable organic materials and to convert the sun's energy into usable energy. Animals and non-green plants are unable to do this. They are dependent upon green plants as their source of foods manufactured from inorganic materials and as their source of usable energy.

Second, only a small part of the land crop plants in use today are edible. Only about one-half of the dry weight of land crop plants is nutritive. The remainder is composed of cellulose and other indigestible materials. *Chlorella* is a one-celled plant and therefore lacks indigestible structural parts such as roots and stems. Nearly all the food it manufactures is converted into edible material.

Third, over 50% of the dry weight of *Chlorella* is protein which is more than is found in the edible portions of higher plants. This protein is excellent for human consumption for it contains ten of the essential amino acids and the proteins are of an easily digested type.

Fourth, *Chlorella* is more efficient in its use of sunlight. Since the sun's light is our ultimate source of energy, efficient use of sunlight is of paramount importance.

There is no need for producers of our present land crop foods to worry about *Chlorella* replacing these crops in our economy at the present time in the United States. In our country, where there is still much land available for food crops, there is little need for large-scale production of algae. However, in countries where there is little or no fertile land, algal culture is of great importance. No soil is required. No rain is needed. There is no need to spray with insecticides. There is no laborious cultivation involved. All that is needed is an abundance of sunlight, a water supply, carbon dioxide, and nitrogen compounds. Cultivation can be a year-round process.

By now, you may be thinking that we shall be growing *Chlorella* in our backyards or on our roof-tops and that little *Chlorella* farms will be springing up all over the world. If I have made it appear that algal culture is a simple process to be carried out by any one of us, let me make it clear that this is not so, at least not at the present time. There are many problems in large scale cultivation of algae which are not easily solved. Some have been overcome, but many remain unsolved. From early reports, I was under the impression that soon one would be seeing large open ditches near irrigation waters teeming with *Chlorella*. All one needed to do was to scoop the plants out of these ditches by the carload. Such "open ditch" experiments were carried out in Venezuela (4) but the yield was extremely low. This is not the way in which we plan to grow this crop. Here are a few reasons why *Chlorella* must be grown in specially constructed tanks or plastic tubing under controlled conditions.

Cultivation problems may be classed under two headings, namely, (1) light and temperature and (2) raw materials. To understand why these are problems, one must understand what is meant by the growth of unicellular organisms. The growth of these organisms does not mean merely an increase in size of individual cells but an increase in the number of cells present. A *Chlorella* cell actually never dies under ideal conditions; it merely divides to become two new cells. Of course, there must be a slight increase in size of each of the new cells before they divide since each at the beginning is just one-half the size of the original cell. However, to get a high yield of this crop there must be a steady increase in the number of cells present. There are about 20 million *Chlorella* cells present in one quart of a moderately thin suspension of *Chlorella*, and under optimum conditions this number should double in twenty-four hours (4). However, this will not occur if environmental conditions are unfavorable.

Chlorella cultures increase in number most rapidly when exposed to bright light. Yet, the most efficient conversion of light into bound energy in food is in dim light. A compromise intensity must be used.

Only a small part of the light falling on the plants is absorbed. The rest is converted into heat.

This brings us to the problem of temperature. The highest yields are obtained in experiments when temperatures range from 86°F. in the day to 68°F. at night. Higher temperatures decrease the yield. At the present time it is necessary to cool outdoor cultures artificially. This may not be necessary in the future if a high-temperature strain of *Chlorella* can be used.

The photosynthetic process is most efficiently carried on by plants when they are exposed to intermittent light. The first phase of the photosynthetic process requires light for splitting water into hydrogen and oxygen. The hydrogen is then combined through a series of steps with carbon dioxide until the final product, a simple sugar, is formed. These later steps do not require light. Experiments show that the most efficient use of light occurs when the plants receive light in flashes, for most of the process can be carried on in the dark. To simulate the flashing of light, *Chlorella* cultures are agitated so that cells are constantly being brought into the light and then shaded by other cells which are moving into the light.

Carbon dioxide must be introduced into the culture medium. Air alone does not furnish sufficient amounts of carbon dioxide. Two tons of carbon dioxide per ton of dry weight of *Chlarella* are required. A mixture of 5% carbon dioxide in air is adequate. But this too must be stirred into the medium so that all parts of the culture will receive equal amounts. Therefore, this requires, along with the agitating machinery, means for producing and introducing the additional carbon dioxide.

In addition to the above factors, fixed nitrogen in the form of potassium nitrate, ammonium sulfate, and ammonia, available iron and other nutrients must be added to the culture.

Lastly, the cultures must be sterile. Protozoa (unicellular animals) and bacteria will feed upon the algae. They also produce by-products toxic to the algae. If maximum yields are to be attained these organisms must be kept out of the cultures.

One of the first pilot plants to be constructed was made by Arthur D. Little, Inc. A flat, thin-walled tube of polyethylene, four feet wide and a few inches high, was used. A 160-foot length held 1,200 gallons of culture (4). This tubing was placed on the roof of a building, and a centrifugal pump circulated the culture. Some of the culture was bypassed through a heat-exchanger to regulate its temperature. About 16 tons per acre per year could be harvested from such a pilot plant. Although circulation, cooling, harvesting, and drying operations did not present unusual engineering problems, machinery had to be set

up to accomplish these jobs. Future commercial plants probably will be set up in large open fields where there is sufficient sun and warmth.

With the present set-up, as it is visualized by research workers, the yield is not high enough to reduce costs below those of existing land crops, such as corn. Even with a yield of 40 tons of algae per acre the cost is about 25 to 30 cents per pound. However, the use of large-scale algal cultures may not be dependent upon the cheapness of the product. In many areas of the world the need for protein is so urgent that cost may not be the determining factor. In some areas starvation is aways a threat.

Algae might furnish food in areas cut off from supplies by war and thus such food would have a survival value.

And lastly, if we establish space stations between the earth and the moon, algal cultures on these space stations could furnish oxygen as well as food for the persons manning the station.

It is agreed that the algae are nutritious. They furnish a high protein yield with most of the amino acids essential for humans. They furnish high carbohydrate and fat yields. And they contain essential vitamins. Yet, will people eat this product? One major field of research lies in the area of food preparation. Can we make this product palatable? Dried *Chlorella* tastes very much like raw lima beans or pumpkin. To some who have tasted it, *Chlorella* has a strong, unpleasant flavor and it often leaves an unpleasant aftertaste. However, when it is combined with other foods in soups and bread it seems to lose this after-effect. Dr. and Mrs. H. Tamiya of Japan (5) have prepared several dishes which included *Chlorella*. They have made ice cream, rolls, bread, noodles, and soup. Dr. Tamiya says that a meal of their noodles smothered in algae sauce (made to taste like soy sauce) is as nutritious as a small steak dinner. However, there is one drawback in the use of algae. Everything in which they are used has a decidedly green color. This is not distasteful in ice cream, but how will people take to green noodles, or green dinner rolls? This may be a problem for advertisers to tackle. We have become quite accustomed to green toothpaste and green chewing gum. The processors may be able to sell green food as well.

To the people of the United States the use of algae as a food still is a novelty. We may read reports of future use or hear announcements of the work of research workers but still we may say "so what?" It is far from a need for us today and it is hard for us to look into a future in which we shall face a food shortage. But, even now, vast numbers of people in other parts of the world need protein foods. Algae may become an important food source for them. Plant biolo-

gists have tackled an interesting problem in algal culture, and the present day research in this field may, in the not-too-distant future, develop into a major food industry.

Literature Cited

1. Reed, Vergil D. American is Growing—are you? *Printer's Ink*, Oct. 10, 1952.
2. Chapman, V. J. Seaweeds and their Uses. Pitman Publishing Corporation, 1949.
3. Newman, Peter. Seaweed Gets Dressed for Dinner. *The Financial Post*, Toronto, Canada, Aug. 28, 1954.
4. Burlew, John S., Ed. Algal Culture from Laboratory to Pilot Plant. Carnegie Institution of Washington Publication 600, Washington, D. C. 1953.
5. Davidson, Bill. Now—Bread from the Sea. *Collier's*, April 16, 1954.

SECOND GREATER NEWARK SCIENCE FAIR APRIL 15–16

The committee for the second annual Greater Newark Science Fair announced today that plans for the contest of scientific projects by area high school students to be held April 15 and 16 at Newark College of Engineering show an early registration of 160 exhibits from 38 schools, twice as many as were shown last year, with 54 schools still to be heard from.

Students from Essex, Union, and sections of Hudson, Morris, Passaic, and Bergen counties will display their projects at the college's Laboratory Building, 367 High street, Newark, before a special judging committee on Friday, April 15. The fair, including winning displays, will be open to the public the following day.

In commenting on the two day event, William Hazell, general chairman of the Fair Committee and dean of administration at NCE, stated that the great increase of exhibits over a year ago was "highly gratifying."

The annual competition was instituted, Hazell said, because science fairs have proved themselves wherever they have been developed as a primary means of interesting our secondary school students in science as a career.

"Whether or not a student winner goes on to the national fair, to be held this year at Case Institute of Technology," he said, "he is sure to gain a new recognition of the dramatic part science is playing in the nation's technological development.

"In the close race that is now being run for scientific and technological supremacy between the Iron Curtain countries and the nations of the free world," Hazell emphasized, "such community-wide projects as this, which include opportunity for so many young people to participate, are an ideal means of insuring that America will stay strong through the difficult years to come."

State and regional winners will compete in the National Science Fair in May for "wish awards," scientific equipment of their own choice, ranging in value from \$50.00 to \$125.00. Winners also attain recognition which, the educator stated, "often leads to fully-paid scholarships granted by leading colleges and universities."

Hazell stressed that students who do not receive top awards will nevertheless obtain recognition on the local level, with awards from local business firms, certificates of merit, opportunities to meet and talk with leading industrialists, and through other means.

The college will offer its plant and facilities for the contest, but, Hazell added, the high school teachers themselves will be the key men and women in preparing their entrants for the event.

The Fair Committee is composed of 31 representatives of business, education, and religious and civic organizations in the greater Newark area.

THE EARLY IDENTIFICATION OF POTENTIAL SCIENTISTS*

SAMUEL W. BLOOM
Monroe High School, Rochester, New York

The need to provide for the education of the superior or gifted child has taken on added significance since the end of World War II. The growing shortage of trained personnel in most fields of endeavor has become a matter of concern to both educators and leaders of industry. There is a scramble for available talent. The time has come for the schools of the country to use every device to identify our potential and to develop it. There can be no question but that better methods of early identification of our superior children could reduce substantially the present wastage of superior talent.

The 1947 Steelman report[1] stressed the scientific needs of the nation. The reports of the Engineering Manpower Commission[2], the National Manpower Council[3], and the U. S. Office of Education[4] have all indicated the need for better identification and more effective guidance of gifted science students.

Field of Science	Peak Years of Productivity	Per Cent Contribution Prior to Age 40
Chemistry	26–30	77
Mathematics	33–37	54
Physics	30–34	56
Entomology	35–39	48

We must develop methods of identifying and speeding up the training of gifted students in order to prepare them earlier for creative work. At present many students of science are not ready to start independent research until their middle or late twenties. Many of their potentially best years are thus lost. Research has indicated that the peak years of productivity come relatively early in the lives of our scientists . . . earlier than many of us would suppose.

* Prepared for presentation for the Fall Meeting of The New England Science Teachers Assn., October, 30, 1954.

[1] Steelman, John R., chairman. *Science and Public Policy*. IV. *The Federal Research Program. A report to the President*. U. S. Government Printing Office, Washington, D. C. October 11, 1947.

[2] The Engineering Manpower Commission of the Engineers Joint Council with offices at 29 West 39th St., New York 18, N. Y. issues a semi-monthly newsletter pertaining to the recruitment and training of engineers and scientific personnel.

[3] National Manpower Council. *Student Deferment and National Manpower Policy*. New York: Columbia University Press, 1952.

[4] Brown, K. E., and Johnson, P. G. *Education for the Talented in Mathematics and Science*. U. S. Office of Education, Bulletin 1952, No. 15. Washington: Government Printing Office, 1953.

Lehman[5] in his recent study of *Age and Achievement* presents some very interesting and provocative data, shown in table (page 287).

Some examples of early achievers who have made major contributions in science before reaching their majority provide us with additional food for thought.[6]

1. Alexandre Bacquerel at the age of 19 discovered "that light affects the resistance value of selenium." This is the basis for our research into photo-electricity and the photo electric cell.
2. Sir Humphry Davy at the age of 20 discovered the anesthetic properties of nitrous oxide.
3. Galileo at the age of 17 gave us the laws of the pendulum.
4. Edmund Halley described sunspots at the age of 19 and at the mature age of 21 made the first complete observation of a transit of Mercury.
5. James Joule described an "Electro-magnetic engine" at age 19 and demonstrated the production of heat by voltaic electricity at age 21.
6. Marconi at age 21 transmitted signals one mile without wires and thus became the father of our radio broadcasting.
7. Nineteen year old Perkin working to discover a synthesis for the preparation of quinine accidentally discovered a compound among the oxidation products of aniline with chromic acid exhibiting tinctorial properties. It was the first synthetic dye.

Many other examples could be given in the field of science as in other fields. The gifted child seems to make his major contributions at an early age. The visitor to any of our nuclear laboratories is impressed with the youth of our more creative workers today. Brookhaven, Los Alamos, Harvard, and M.I.T. are not isolated examples, our creative research is in the hands of youth.

We are a growing nation. By 1960 it is estimated that the population will increase by nearly 30 million. Paralleling this increase is a steady rise in American living standards. Small wonder, then, that we are especially concerned with training our young people to live in, and contribute to this technological world.

The serious engineer shortage is nothing new to any of us. We cannot minimize its importance. However, the shortage of trained personnel is not confined to engineers alone. The number of present day science teachers of high calibre is very inadequate. Dr. Fletcher G. Watson of Harvard reported at the AAAS meeting held in Boston (December, 1953) in considerable detail on *The Critical Years Ahead*

[5] Lehman, H. C. *Age and Achievement*. Pp. 242, 254. Princeton: Princeton University Press, 1953.
[6] *Ibid.*, pp. 200–217.

in Science Teaching.[7] It is predicted that there will be a shortage of 84,000 full and part-time qualified high school science teachers by the 1959–60 school year. As citizens and teachers, we should be greatly concerned with this trend of events.

In the 1953 report of the National Manpower Council[8] it was indicated that only 56% of our high school youth complete high school. 20% of these high school graduates enter college; only 12% (of our high school graduates) graduate from college. Let us look at an even more dismal set of figures. This past year, only about 3.5% of those in the nation's secondary schools took any advanced mathematics courses such as solid geometry, trigonometry, or advanced algebra. In science, percentages are equally as poor. Only 4% took a course in Physics, and, only slightly more (5.9)% took Chemistry. The New York State Regents figures for the past year are not much better than the national average, 4.4% took Physics and 6.6% took Chemistry.[9]

It is estimated that one fourth of the nation's eighteen-year-olds have the capacity for college work.[10] Only 40% of this fourth enter college. Various reasons are given by high school graduates of high intellectual ability for not continuing their education. Finance is one factor to be considered. Another factor is that of MOTIVATION. Opportunities for high wages in industry may be still another factor. Many capable boys and girls simply do not include college as part of their career planning. What a waste of talent!

We, as teachers interested in science, can provide the necessary stimuli and sympathetic encouragement that many able youngsters need. We can instill in these young people an appreciation of the importance and value of science. From the limited numbers of our superior children will come the creative force of tomorrow. The average boy or girl can be trained as a technician, but the real creative work will be done by the individual with imagination and with high general intelligence. He is in our classroom today. We must find him and provide him with the variety of experiences which will bring out his latent talents and encourage him to work to capacity. We can help him acquire the knowledge and appreciation of science and the scientific method. We can provide challenging situations

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[7] *Critical Years Ahead in Science Teaching*. Report of Conference on Nation-Wide Problems of Science Teaching in the Secondary Schools. Held at Harvard University, Cambridge, Mass. July 15 to August 12, 1953. Cambridge: Harvard University Printing Office, 1953.

[8] National Manpower Council. *A Policy for Scientific and Professional Manpower*. New York: Columbia University Press, 1953.

[9] Statistics quoted by Mr. Lang, vice president, General Electric Company. Reported in a letter to the writer, September 30, 1953, by James R. L. Holdsworth of the General Electric Company, Schenectady, New York.

[10] Dael Wolfe, "Future Supply of Science and Mathematics Students," *The Mathematics Teacher*, 46: 225–229, 240, (April, 1953).

and encourage the use of community resources. We must reach him early in his school experience.

WHAT ARE SOME OF THE CHARACTERISTICS OF THE GIFTED SCIENCE PUPIL?

Prior to 1920 it was believed by many persons that very bright and "gifted" children were atypical, immature, and emotionally unstable. Some writers asserted that eccentricity and genius were inseparable, and others stated that the extent of genius was in direct proportion to the amount of instability. The results of such thinking were unfortunate. The stereotype of the "genius" and of the gifted child persists to this day in the thinking of many people.

Contrary to this concept, a number of studies and reports[11] during the past thirty years have indicated that the typical gifted child is physically stronger, socially more secure, and emotionally more stable than the average child of his own chronological age. In addition, he is more alert, more responsive, and more eager to learn. There is marked agreement in the findings of Terman,[12] Witty,[13] and others. A composite list of the traits most frequently found in gifted students includes: a high general intelligence, high verbal comprehension, superior vocabulary, intellectual curiosity and imagination, the ability to assimilate and generalize, objective self-analysis, persistency, and an insight that is often truly remarkable.

Paul Brandwein[14] of the Forest Hills High School (New York) states that in identifying students with high potential, it was found that they possess:

1. Very high intelligence as measured by standardized I.Q. tests.
2. High mathematical ability.
3. High verbal ability.
4. High manipulative skills—the ability to use their hands.

He indicates that "high level ability in science is a function of high general ability and cannot, at present, be isolated as a separate hereditary factor arbitrarily called, "science talent." He follows this statement up with the observation that young students with high achievement in verbal and mathematical skills can develop a high-level ability in science *if given appropriate opportunities* including skilled teaching and wide training in laboratory science. Anne Roe in her classical study of physical scientists comes to a similar conclusion.[15]

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[11] Paul Witty, editor. *The Gifted Child*. Boston: D. C. Heath and Company, 1951.

[12] L. M. Terman and M. H. Oden. *The Gifted Child Grows Up*. Stanford: Stanford University Press, 1947.

[13] Paul Witty, "Educational Provision for Gifted Children," *School and Society*, 76: 179–181 (September 20, 1952). See also: *School and Society*, 78: 113–119, (October 17, 1953).

[14] Paul F. Brandwein. *Scientific Monthly*, 64: 247–252, 1947. *Science Education*, 36: 1 (February, 1952). *Science Education*, 35: 251–253, (December, 1951).

[15] Anne Roe, "A Psychological Study of Physical Scientists," *Genetic Psychology Monographs*, 43: 121–239, (1951).

If we are to guide the gifted high school pupil successfully, we must identify him accurately. With the advent of the intelligence test, children I.Q. 130 and higher were referred to as "gifted." In the early studies of the distribution of intelligence, it was found that these children constituted about 1% of the entire school population. The Educational Policies Commission[16] pointed out that such a line of demarcation is arbitrary, and suggested that high school pupils with I.Q. 137 and above be considered as highly gifted, and that moderately gifted students be identified by I.Q. ratings of 120–137. Such a practice results in the designation of about 10% of our high school students as moderately or highly gifted. In the Long Beach (California) schools, the 97th percentile based on intelligence and reading test scores is used as the line of demarcation for very superior pupils. In San Francisco, the top 2% of the school population is considered gifted. A veriety of criteria is used in other communities.[17]

There is no easy way to identify the gifted or superior pupil in science. The use of the I.Q. as the sole criterion of superiority brings about the selection of many children who possess high abstract or verbal intelligence. However, if children are reared under unfavorable socio-economic circumstances, the verbal test of intelligence has a limited value in determining their capacity. A more practical approach was discussed at the 68th Annual meeting of the New York State Association of Secondary School Principlas:[18]

> It was pointed out that this rapid learner constitutes somewhere in the neighborhood of about 3% of the average population, and that we should start early in the school career to identify these people. They can be spotted in some instances by high performance on standard tests and have high achievement scores. They also are the children who finish their work first. However, they also may be discipline problems, and in some instances may be the children who do the poorest on standardized or other tests. Consequently we can not depend upon any one factor alone but must combine all of these characteristics, together with the teacher's estimate.

A pragmatic approach to the problem of identifying our potentially able science people has become necessary. From a practical standpoint, let us see how some schools identify their gifted science students and what they do for them. The examples represent comprehensive high schools similar to the schools we find in the New England area both as to size and student composition.

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[16] Educational Policies Commission of the National Education Association of the United States and the American Association of School Administrators. *The Education of the Gifted.* Washington, D. C.: National Education Association, 1950.

[17] Paul Witty and S. W. Bloom, "Science Provisions for the Gifted," *Exceptional Children*, 20: 244–250, 262, (March, 1954).

[18] *Providing a Program for the Superior Student.* Proceedings of the 68th Annual Meeting of the New York State Association of Secondary School Principals. Held at Syracuse, New York, December 14–16, 1952, pp. 44–48.

The North Phoenix High School, Phoenix, Arizona

Let us start by analyzing the methods used at the North Phoenix High School. Three teachers—a biologist, a chemist, and a physicist—work together as a team in developing scientific talent at their school. How do they do it?

1. *Picking them early.* Identification by the General Science or Biology teacher at the 9th and 10th grade levels of pupils with unusual interest and ability in science.
2. *Guiding them along.* One of these teachers assumes the sponsorship of each pupil and serves as a science advisor to him.
3. Pupils are given the opportunity to work before and after school in the field of their choice. Laboratories and workshops are available under the supervision of one of these teachers.
4. Promising students are used as laboratory assistants and as workers in the stockroom. This experience is valuable to the pupil not only because he can familiarize himself with the materials of science, but also because he can devote some of his time to project work.
5. Ideas for projects come from a variety of sources such as: specialists in the field and universities in the area. A list is kept of all members of the community who can be called upon to provide resource material and who may be interested in assisting promising boys and girls.
6. Community resources are utilized to stimulate interest. Field trips are frequent as part of both class and club work.
7. A very important factor is the active science clubs we find here.

The success in science at the North Phoenix High School may be summarized as the result of early identification, individual guidance, use of community resources, a differentiated program, and team work among members of the science department. Although this school has a comprehensive testing program, please note that selection for special work in science is based primarily upon *interest* and *ability* as demonstrated in the actual teaching situations.

Oak Park High School, Oak Park, Illinois

At the Oak Park High School, guidance is given to the gifted student through ability and aptitude testing, through acceleration in courses where such acceleration seems feasible, through ability grouping within certain courses, through career conferences, and through both group and individual counseling. Such motivating and challenging activities are used as:

1. Planning science assemblies.
2. Taking part in science contests.

3. Tutoring slower students.
4. Acting as laboratory assistants.
5. Taking part time jobs in industry where some science training is required.
6. Participating in Junior Academies of Science, the Science Talent Search, and the Future Scientists of America programs.

The matter of ability grouping is of particular interest to me as a chemistry teacher. At Oak Park, there are three levels of ability grouping in chemistry. There is ***regular chemistry*** with emphasis on mathematics and quantitative experiments. The class is held to rigid standards. Admission to this class is based upon a screening by the head of the science department.

Chemistry M attempts to do the same work as regular chemistry but with less emphasis on the mathematics. Generally, not as much ground is covered.

Chemistry L is a course in everyday chemistry, "living chemistry." It is designed for those pupils whose records indicate that they may have difficulty in either of the other two chemistry classes. The median I.Q. for this group is between 90–95.

Where it is possible to have some sort of ability grouping, the standards of the group can be up-graded. Pupils will attempt to keep up with their peers, and are thus stimulated to work more nearly to their capacities.

This school has a very active science club program which includes: a Freshman Science Club, a Biology Club, and a Chemistry Club. It seems that an active science club program is a definite motivating factor for boys and girls in science.

Monroe High School, Rochester, New York

Selection for the ***Experimental Honor Program of Studies*** at the Monroe High School, Rochester, is not confined to any one criterion. Identification of the superior student is based on a comprehensive testing program which includes: group and individual tests, achievement tests, interest inventories, school marks, and teacher recommendations. This program is designed to permit curriculum adaptation to the unique needs of the superior boy and girl and to make possible a suitable rate of educational advancement.

Ninth grade pupils prepare for the Regents Earth Science examination usually taken at more advanced levels. This is followed by a required year of Biology. Senior science may be either Chemistry or Physics. In many cases both are taken.

Teaching practices differ from regular classroom procedures in the greater use of long term assignments, special reports on items of scientific interest, special project work, frequent university and

industry visitations, participation in science fairs, Science Talent Search, and in the Science club. We at Monroe High are encouraged by our results but it is too early to properly evaluate the program.

The Watertown High School, Watertown, Massachusetts

The Watertown High School has received recognition for its *Science Seminar* which is used as a device to stimulate and encourage pupils in science. MacCurdy[19] reports that those students who are planning a definite career in science, demonstrate superior interest, aptitude, and performance are invited to join the Seminar group. Members of the Seminar meet weekly during school time to work on projects, report on current scientific developments, plan and give demonstrations, hear speakers, participate in science contests, and other related activities.

Here is one example of a method used in this area for stimulating science activity. Similarly, a very active Science Seminar is reported at the Plymouth High School (Mass.) under the leadership of C. H. Young. Every possible teaching device should be explored to make additional opportunities available to our potentially gifted science people.

Concluding Statements

There are many, many more examples of how different schools are providing for their intellectually gifted boys and girls in science. Schools are attempting to provide for the gifted through: enrichment, acceleration, special classes, extension of experiences by use of workshops, clubs, laboratories, the library, guidance and counseling, and extensive use of community resources.

A procedure or administrative device which may be satisfactory in one school situation may prove inadequate in another. However, some of the devices and procedures have not been well-received among American educators. I found, for example, the use of acceleration is rather generally frowned upon. On the other hand, enrichment, whether in special classes, special schools, or within the regular classroom is widely endorsed. However, with expanding enrollments, it is recognized that it is increasingly difficult for the classroom teacher to provide adequately for gifted pupils.

What Can We Do in Our School for the Gifted Science Pupil?

1. Early identification by whichever means we use is essential if we are to provide for the child's maximum growth. If potential

[19] Robert D. MacCurdy. Reported from an interview between the writer and Mr. MacCurdy, September 15, 1954

ability is present but remains undeveloped for too long a time subsequent efforts to develop it may be futile.

2. If the school is large enough, some form of ability grouping may be desirable. This does not imply neglect of the less able, but greater opportunities for all our boys and girls.
3. Subject matter of increasing difficulty should be provided to furnish new and challenging situations. A wealth of supplementary material should be provided.
4. Give the student the opportunity to find out things for himself; the chance to work on his own. Make the laboratory readily available.
5. Hobby activities can be encouraged; many boys learn through manipulation and gadgeteering.
6. Encourage participation in science club programs, science seminars, contests, etc. These are valuable aids in maintaining interest in science beyond the basic work of the course.
7. Greater use of community resources, outside speakers, field trips, and similiar activities should be encouraged. These are all facets in providing for the enrichment of the regular science course and a must for the gifted science pupil.
8. A close relationship between pupil and teacher encourages the student to extend himself. Given the encouragement, the devoted student will carry on, on his own.
9. And last, the vocational aspects of science should be emphasized. The gifted child should be given every encouragement and consideration to enable him to select wisely his vocation—be it engineer, doctor, physicist, or science teacher.

One factor that seems self-evident but can bear considerable reiteration is the fact that wherever we have a school or a class in which unusual work is being performed in science we find an effective, dynamic personality—the teacher. Whether the school be large or small, new or old, it is the man or woman in the classroom who makes the difference. It is the teacher who is important in identifying potential science talent and encouraging students possessing this talent to continue their scientific education. May each of us have some measure of success in this all important work.

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The 7th Institute for Teachers and Professors of Mathematics, sponsored by the Asso. of Teachers of Mathematics in N.E., will be held at Middlebury College, Middlebury, Vt. August 18–25, 1955.

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IS ALGEBRA A "TOOL SUBJECT?"

GEORGE L. KEPPERS
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Whenever the average person hears algebra being discussed, he immediately thinks of something far beyond his power of comprehension. In the discussion that follows the writer wishes to point out a few fundamental ideas in regard to the value and presentation of algebra in the high school as either a "tool subject" or a "thought subject," with special emphasis on the latter.

Through the study of algebra the pupil is to be trained to think clearly, to draw correct inferences, to develop and use good judgment and to make fine discriminations. At the same time, he is to become proficient in the mechanical processes of algebra and to acquire the ability of perform them correctly when they occur in problem situations.

Much of the algebra taught today can impinge upon the immature mind without helping in the least to mature it. No attempt will be made to state which parts of algebra are and are not capable of developing the immature mind, but it is known that, "Algebra was originally included in the school curriculum for a thoroughly humanistic purpose; it is the only elementary discipline which furnishes material for abstract thinking and caters to the development and pleasure of the faculty called pure reason."[1] The educational value of algebra lies in the fact that it is a definite new step toward abstract conception. Algebraic thinking lies just above the arithmetical level and may be defined as "generalized arithmetic." In algebra we must conceive the meaning of "*a* and *b*", because it cannot be perceived as "3 and 4" can in arithmetic. The whole task of training the discursive reason, which lifts man above even the cleverest of other creatures, develves upon the teacher of algebra.

"The mastery of algebra—even elementary algebra—requires two intellectual functions; first, abstraction or the recognition of general properties and relationships, and second, manipulations or deductive reasoning."[2]

The importance of using the study of algebra as a means of training in functional thinking is being recognized more and more. It has long been emphasized by leading mathematicians and has been widely discussed in mathematical journals, teachers' conferences and committee reports. The suggestion has been offered that in the reorganization of secondary mathematics the function concept be made the

[1] Langer, Susanne K., "Algebra and the Development of Reason," *The Mathematics Teacher*, Vol. 24 (May, 1931), pp. 285–286.

[2] Langer, Susanne K., *op. cit.*, p. 289.

unifying principle. Indeed, without functional thinking there can be no real understanding and appreciation of algebra.

The demand for emphasis on functional thinking has been advocated, but many authors and teachers still pay little attention to it. On almost every page of algebra and geometry texts opportunities for training in functional thinking are afforded, but no systematic use of them is made. Much supporting evidence could be offered in defense of the statement that, "If we wish to have functional thinking take place, we must teach for it." It is the old saying in different language, "We reap only what we sow."

Possibly one of the best examples to illustate that functional thinking and transfer does take place when the teacher looks for it, is in neatness. In the experiment the teacher of algebra was to use all efforts possible to secure neatness in the class of algebra. The improvement in algebra was very noticeable, but the same pupils showed not the slightest improvement in language and spelling papers. In a later experiment neatness not only as a habit but as an ideal was held up in not only a particular class, but in dress, appearance, business, in fact everywhere except in other classes. The results proved very definitely that neatness made conscious as an ideal or aim in connection with only one school function does function in other subjects.

The possibility and desirability of transfer and functional thinking cannot be questioned, for to say that would be saying it was impossible for the human being to learn. The problem thus becomes one of so organizing the materials and methods of instruction to guarantee the largest amount of positive functional thinking and transfer.

In the verbal problems of algebra the pupil is frequently expected to formulate the mathematical law which expresses a relationship. This is common in applied problems of which the following illustrations are typical examples: The area of a square depends upon the length of the side; the circumference of a circle depends upon the radius; the cost of wood depends on its volume. Statements like these offer opportunity for functional thinking by discussions of the factors involved in the problem and of the nature of the relations between them. Teachers, however, are likely to ignore the relation aspect in verbal problems and to pass directly from the statement to the mathematical law and then to the solution of the equation. The pupil is thereby deprived of training in functional thinking.

Numerical facts are commonly presented in the form of tables. It is then necessary for the reader to interpret the facts presented in the tables to appreciate their meaning. Some tables contain facts that are related to each other by precise mathematical laws. In others relations exist which cannot be expressed precisely. In still others

there exists correspondence, but no relationship. In all cases there are opportunities for studying the facts from the stand point of functional relationship, that is, of dependence and correspondence. When a relation is stated in words the pupil may have to construct his own table to make the relationship clear to himself. Tabular representation is widely used in the study of mathematics and without emphasis on the relationships involved in the tables, the pupil may be deprived of much valuable training in functional training. Indeed he may fail to appreciate the full meaning of tabular facts.

In solving problems the formula is frequently taught as an "abbreviated rule" of a verbal statment. As such it simply states a procedure to be followed. Thus the formula $A=lw$ directs the pupil to multiply the length by the width to find the area of a rectangle. He is likely to follow the directions without any knowledge of the fact that the formula expresses dependence or relationship between the variables A, l and w. Many texts give three formulas, one for each of the variables. The pupil learns all three, but he gives no thought to the way they are related to each other, unless his attention is called to the relationships, which is the duty of the teacher. E. R. Breslich states that "best results are obtained if the pupil, in solving problems of the type given above, thinks of one relation only."[3] If he understands that relation thoroughly, then, in the solution of a problem, he will always go back to it and solve it for the required number rather than choose the one which fits a particular problem.

Evaluation exercises with formulas offer further opportunity for functional thinking. However, this opportunity may be entirely lost when the mind of the pupil is centered wholly on this sort of work, because the formula is thus looked upon as a basis for computation only. A study of the changes produced in the formula by changes of the values of the variable should go hand in hand with the calculation of the values. Dependence and correspondence should always be made to stand out clearly.

As in the formula, several aspects of the equation are to be emphasized if real understanding is to be attained. Some equations are statements of mathematical laws, others equate two expressions denoting the same number and still others are symbolic translations of verbal statements. The pupil may think of the equation simply as a question asking for the value of the unknown number. For example, to find the angles of a triangle, if the first is one-half as large as the second and the third four times as large as the first, he may solve the resulting equation without giving any thought to the relation involved. On the other hand, he may think of the statement $a+b+c$

[3] Breslich, E. R., "Developing Functional Thinking in Secondary School Mathematics," *The National Council of Teachers of Mathematics*, Third Yearbook, 1928, p. 48.

= 180 as a relation between the three angles of any triangle. As soon as the sizes of two are known, that of the third is fixed. Such considerations call attention to the functional aspect of the equation. In the same manner all equations may be considered as expressing relations.

In the teaching of graphs, we often overlook the fact that making the graph is not an end in itself, that it is equally important that the pupil learn to "think graphically" of relationships. Many textbooks still present the graph as a separate topic and fail to make use of representation later in connection with other topics, even in cases where it might be a real help. Hence, graphic representation does not become a method which the pupil employs as effectively in dealing with quantitative relations as he does other mathematical methods. Not only the making of the graph but the Interpretation of the graph and the study of the relations involved are the ends to be attained.

It is unfortunate that for a long time it was maintained that algebra furnished a general training of the "reasoning faculties," as if a certain power might thereby be developed to function in all situations. The problem of "transfer," however, need not be gone into here more than to note that it is now generally accepted that transfer is possible.

If Mathematical teaching in the past has not paid sufficient attention to gathering and organizing data, this was partly due to the fact that scholars in other fields were not always cooperative. They shut themselves away from mathematical methods. But this has now changed, and the development and the wide use of statistical methods have greatly increased the area in which significant quantitative work is possible. A certain knowledge of basic mathematics is required in these areas. A fair competence in algebra is needed if one is to understand concepts and procedures beyond the most elementary ones. In a way algebra may be a "tool" for statistical work but a tool in a very fundamental sense, since it is woven closely into the texture of the subject and into the thinking which is involved. That something far more than routine skill is required becomes apparent when the subject is carried into the range of probabilities, a field into which it inevitably moves as soon as measures of reliability are introduced.

The truth of what has just been said is being constantly demonstrated by individuals attempting to do statistical work without adequate preparation. The difficulties which so frequently take them to a mathematician for aid usually center around the meaning of things. Actual use of formulas may have caused no trouble, but neither the ideas from which the formulas were derived nor their implications are understood. The person in distress has usually obtained a number of whose accuracy he is sure, but whose meaning quite confounds him.

Such a situation is evidence not of lack of numerical adroitness but of comprehension. The person may be bewildered solely because he does not have at his command the only language which will allow one to "think through" the subject he is trying to handle. Such unhappy situations as this will be corrected only when mathematics is rightly viewed as essential to clear thinking in certain domains, and talk of it only as a "tool subject" has ceased.

Until recently there has been very little inductive thinking in algebra. Comprehensive books on algebra have frequently contained a chapter with the austere title "mathematical induction," probably poorly understood and productive of little result unless the pupil went considerably beyond algebra. There is now, as mentioned before, a definite trend toward leading pupils into new topics through their own experiences. The possibilities are certainly numerous, and it is hoped that algebra will emerge finally as the vehicle through which may be obtained impressive experiences in inductive as well as deductive reasoning.

In conclusion it might be said that, for algebra to be of the greatest value to the student, it must be thought of not only as a "tool subject" but more extensively as a "thought subject." This statement should give the teacher of algebra a firm conviction that algebra can be of the greatest possible use in achieving the highest aim of education, which is to produce "thoughtful thinkers." It should be noted that in the study of algebra the actual, supreme result is not only algebraic attainment, ability or skill; it is the student himself, as represented in what he has become through the self-directed, systematic exercise of neatness, judgment and thoughtful thinking possible in algebra. It was illustrated that the utilitarian has value primarily for the specialist, while the non-utilitarian has value from the humanistic viewpoint as well, which is developing functional thinking on the part of the student.

HIGHWAY OF FUTURE WILL HELP DRIVER STEER CAR

Motorists of the future will drive on highways that help steer the car and on which dips and curves cannot be felt.

Highways which also encourage drivers to travel in the proper speed lane because it would cause continuous strain on the driver to do otherwise were also envisioned by Phil Pretz, executive engineer of the engineering staff's vehicles testing office, Ford Motor Company.

He said that "pavement geometry" would be used to bank curves so that a blindfolded passenger going around this type of turn could not tell he had changed direction.

During a driver's momentary lapse the highway would steer the car, Mr. Pretz told members of the Society of Automotive Engineers in a meeting at Indianapolis.

"SLOW MOTION MUSIC" WITH TWO PENDULUMS

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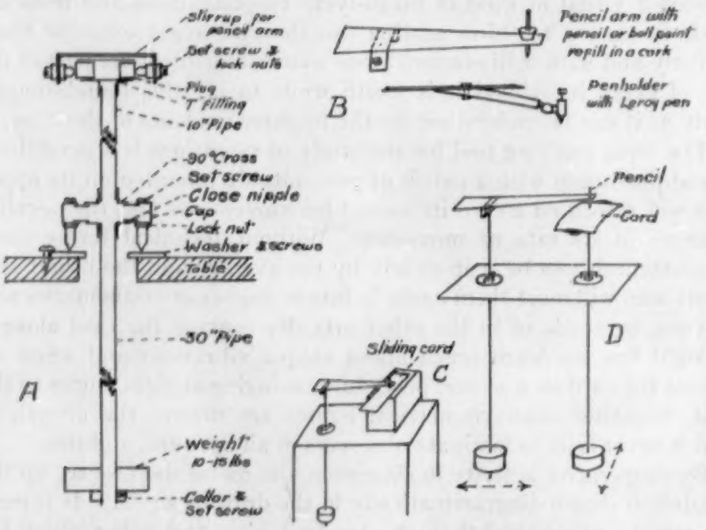
In our music class we were discussing the production of musical sounds. We had the usual tuning fork and stretched string and each member of the class had had the opportunity of seeing and feeling the vibrating bodies as sound was being emitted. No great interest was created because the general idea was already familiar that sounds come from vibrations. The teaching opportunity here was not merely to show that sounds come from vibrations but to lay a foundation for the understanding of the nature of sound-producing vibrations. We needed a visual method of magnifying the vibrations and reducing their frequency to "slow motion" so that we might examine them directly and with deliberation. Since sounds and music are part of the life of every individual it is worth while to lay this foundation as early as it can be understood by the brighter students of the class.

The ideal teaching tool for the study of vibrations is a pendulum. A rod-pendulum with a pencil or pen suitably mounted on its upper end will record on a card its to-and-fro movements and the peculiar changes in its rate of movement. Without technical terms these fundamentals can be seen clearly by the average and the bright students who will meet them again in future studies of mathematics and physics, in music or in the other arts. By moving the card along a straight line we learn much about simple vibrations and when we mount the card on a second pendulum, swinging at right angles to the first, beautiful near-symmetrical figures are drawn, the growth of which never fails to fascinate observers of all ages and abilities.

By cooperative activity in classroom and metal shop we set up the pendulum shown diagrammatically in the drawing at "A." It is built up mainly of one-eighth inch standard pipe and other plumbing fittings. A right angle "cross" has a ten-inch and a thirty-inch piece of pipe threaded into its upper and lower arms respectively and the two horizontal arms are fitted with "close nipples" cut from threaded pipe. Standard "caps" are screwed very tightly on the nipples. Holes are drilled and threaded vertically through the caps, steel set-screws ground to conical points are set in them and locked with nuts. The set-screws stand in two accurately spaced centre-punch marks on a heavy washer, their points forming a fulcrum on which the pendulum swings very freely. (Apply oil). The washer is centered over a 1½ inch hole in the table or a stiff board. A weight of ten to fifteen pounds is supported by a collar clamped adjustably on the longer pipe by a set-screw. A standard "T" fitting is screwed to the upper end of this pendulum and the horizontal openings of this T are filled with stand-

ard "plugs" each centre-punched at the intersection of its diagonals. This fitting is ready for attachment of the pencil-arm. The pencil-arm, B, is a very light, tapered strip of wood about 15 inches long, mounted on a stirrup having two short, pointed set screws (with double lock-nuts) whose points fit into the punch marks on the plugs as shown. The stirrup is attached by short screws at about three inches from the broad end of the wood. The drawings show how the parts are assembled.

The "table" shown in Figure A upon which first one, and later the two, pendulums are supported is a rigid board about 24 by 8 inches with two holes $1\frac{1}{2}$ inch in diameter at a distance of about 12 inches between centres. Concentric with each hole is a heavy one-inch



Sketches (Not drawn to scale) of Pendulums for Recording Vibrations

washer, held in place by three screws spaced around its rim. The board may be supported on two desks or by clamping one end to a table and supporting the other on a vertical board or stick. Lengths and distances are adjusted so that the pencil of pendulum No. 1 rests at the centre of the 5×8 inch curved (or flat) platform of wood or metal on the upper end of pendulum No. 2. Figure D.

In search of answers to questions about vibrations in our music class we first set up the single pendulum without its pencil-arm. We set it swinging and watched it. Soon nearly everyone in the class had observed that, as a pendulum swings, there is at each end of its movement a point at which it comes to rest (Observation 1). Some next

observed that when near its points of rest the pendulum moves quite slowly and when near the middle point of its swing it moves much more rapidly (Obs. 2). The observers are now ready to realize that pendulum vibrations are not simply zig-zag motions with sudden reversals of direction but are smoothly changing motions: SLOW, FASTER, SLOW, STOP, REVERSE, SLOW, FASTER, SLOW, STOP, REVERSE, and so on.

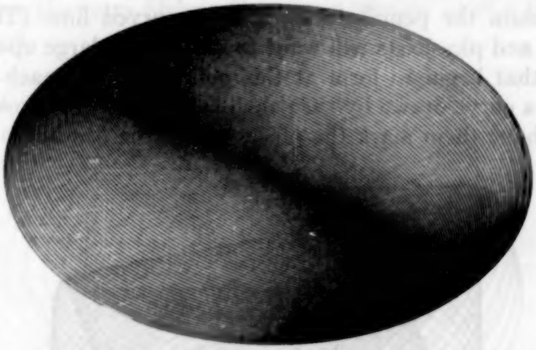


FIG. 1. The "Unison Spiral" drawn by two pendulums tuned to the same frequency and swinging at right angles to one another.

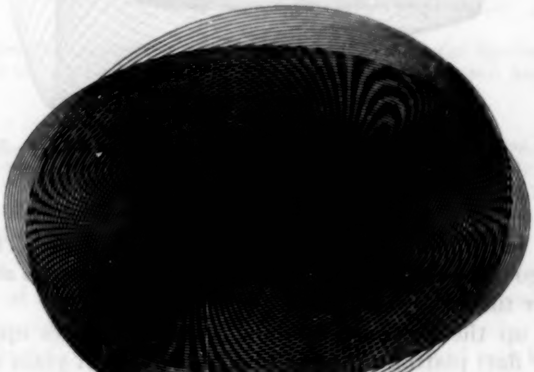


FIG. 2. When one unison spiral is superimposed upon another "shot silk" patterns with reversed symmetry appear.

To make clear to all that the motion of the pendulum changes always gradually, never suddenly, we attach the pencil-arm B to the top of the pendulum and place a long card on a box under the pencil-

point as at C. We set the pendulum swinging and observe that the pencil draws a straight line on the card, stopping at each end to return nearly, but not quite, to the starting point (Obs. 3). We pause here also to verify Observations 1 and 2.

To make the pendulum show us more clearly where in its swing it is gaining and where losing speed we try moving the card along a straight line at right angles to the swing. As we thus combine a straight-line motion of the card with the special to-and-fro motion of the pendulum the pencil draws a wavy curved line. (The mathematicians and physicists will want to stop and enlarge upon the new concepts that begin to form at this point. We give each student a card with a curve drawn by the pencil back and forth across a middle line, and have them mark the places where the pendulum was stop-

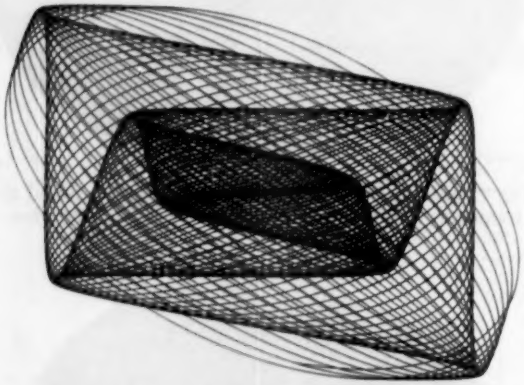


FIG. 3. When one pendulum gains slightly upon the other (i.e. near unison) the number of swings gained is recorded in the figure, as "beats" show difference in frequency of sound vibrations.

ped, slow, faster, slow reversing, etc. Because our project began in music we go on to the next step, leaving the mathematics and physics for another time.

We set up the second pendulum, attaching to its upper end a curved (or flat) platform instead of a pencil-arm. A plain index card is clipped to the platform (D). The pencil may be retained or a ball-point pen used. Much more striking results will be obtained however with black ink in a draughtsman's lettering pen such as Leroy No. 233–000 with holder 3234–1. A small weight on the pencil-arm may be used to increase or decrease the pressure on the pen.

The two pendulums are mounted to swing at right angles to one another and are tuned to equal frequencies, 36 being the most convenient for later changes. We show that either pendulum swinging

alone produces a straight line, verifying our early observations. Then we set both swinging and lower the pen to the card. Few observers are prepared for the result. Beautiful "Unison Spirals" are drawn as the pendulums swing freely and as their swing gradually dies down, one usually coming to rest before the other. No two spirals are alike though all are similar. In the music class we do not mention the three factors that determine the figure and that by their variation give rise to the variety of forms, (frequency, amplitude and phase) nor do we use the term Simple Harmonic Motion until a later discussion period.

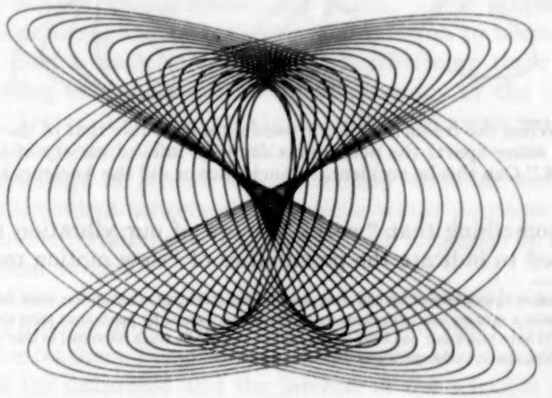


FIG. 4. When the frequencies are in simple proportions the figures are regular. The figure for the Do—Sol chord (2:3) has 2 loops on one side and 3 on the other.

After unison figures have been made for all to take home, the weight at the lower end of the card pendulum is raised to give higher frequency of swing or vibration. When the frequencies are adjusted to 36 and 45 (4:5) we have the "do—mi" chord; at 36 and 54 (2:3) we have the "do—sol" chord and at 36 and 72 (1:2), the octave. A new family of figures appears with each cord, each with an infinite variety of similar forms.

We do not follow the theory far at this stage and age but some bright heads will wonder why there are 2 loops and 3 loops respectively on the two adjacent sides of the figure of a 2:3 chord and especially why the figure for an octave happens to be the figure "8"! It seems fitting that at random frequencies we get tangled figures that look like discords. These merge into the chord figures and at frequencies just off unison they become orderly in a way that represents the "beats" heard when two notes of slightly different pitch are sounded together. At the end of our experiments we have raised

many questions that we have not answered, bright minds have been set thinking and even the slow learners have seen that music has foundations in the natural motions of freely-vibrating bodies.

The study of vibration figures offers endless challenge to the mathematician, the musician, the artist and the hobbyist who delights in

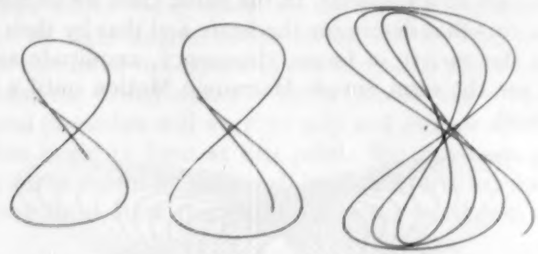


FIG. 5. When the frequency of one pendulum is double that of the other (as in sounds an *octave* apart) the pendulums draw an infinite variety of forms of the numeral "8." Can this be accidental coincidence or did the Ancients know?

making something that "works." A few of our vibration figures are reproduced to indicate the possibilities of "slow motion music."

NOTE: Vibration figures formed by high frequency tuning forks and other devices were described by Jules Antoine Lissajous a century ago but references to the figures formed by pendulums seem scarce. The writer and his students have found only one book on the subject and will be much interested to hear of any references known to readers, also to exchange figures drawn by pendulums.

FELLOWSHIPS AT M.I.T.

A national competition for fellowships for high school teachers of chemistry, physics and biology throughout the United States and Canada to attend a special program at the Massachusetts Institute of Technology during the summer of 1955 was announced by M.I.T. this week.

Dr. Ernest H. Huntress, director of the M.I.T. Summer Session, disclosed that generous assistance from the Westinghouse Educational Foundation will make possible a total of fifty fellowships of $250 each to help meet the costs of attending a special program.

This year's fellowship winners will attend a six-week program of study at M.I.T. from Monday, June 27, through Friday, August 5. Designed by a special faculty committee, this program will provide a review of fundamental subject matter in physics, chemistry and biology, and a survey of recent scientific developments not only in these fields but also in meteorology, geology and aeronautical engineering.

Time will be reserved during the program for informal conferences on teaching methods and for inspection trips to many laboratories at M.I.T. All instruction will be given by M.I.T. faculty members with possible assistance from other educational groups in the Greater Boston area.

Further information on the Science Teachers' Program, and application blanks for the Westinghouse Fellowships may be obtained from the Summer Session Office, Room 7-103, Massachusetts Institute of Technology, Cambridge 39. All such applications must be filed by April 1, 1955.

WHY DEMONSTRATIONS?*

BEATRICE M. MOORE
Muskegon Heights, Michigan

Why is science such an important part of our elementary curriculum today? The answer is simple. Science can be found anywhere, everywhere. Science is anything. It effects our lives at all times. Ours is a scientific world.

A finger is being pointed at us. We are being asked to spark more interest in science among elementary pupils. These people believe that it will encourage more boys and girls later on to become scientists. This field is desperately in need. Furthermore these individuals are asking us to help overcome the illiteracy of the people in the United States. They are asking us to help do away with patent medicine hounds and chlorophyll consumers.

The beginnings of science for elementary children were in the work of independent writers about science whose purposes were instruction and entertainment. They wrote with emphasis on aesthetic and emotional values.

With the rise of new applications of science in industry and medicine a great interest arose. This brought about a division in the thinking of science teachers. Personal enjoyment was to be obtained through the eyes of the naturalist and the interest of the scientist in a systematic knowledge and means for extending it. The controversy centered around Nature Study versus Formal Science. Then, a new definition of science for the elementary school grew out of the studies of child growth and development.

This morning we are going to think about one of the most important techniques used in the teaching of science, the demonstration. "Why Demonstrations?"

What is your aim in teaching science? Is it to fulfill a curriculum requirement? Is it to bring experiences to your boys or girls that are concerned with identification? A case in point would be the teacher who collects and has the boys and girls collect seeds in the fall and very neatly and properly labels each kind. Or is your aim to provide experiences that teach generalizations and principles so that children can use them in better understanding the world about them? Let me repeat. Is your aim to teach generalizations and principles? If you mean to do this, the children will not only collect seeds but they will learn about the function of a seed and the importance of the lowly seed in their lives. They will learn that there

* Presented at the Elementary School Science group meeting of the Central Association of Science and Mathematics Teachers at Chicago, November 27, 1954.

are hundreds of plants that are grown from seeds; that plants come from seeds; that plants require water, light, and soil. And to push these generalizations a little further I want to read a poem "To a Soy Bean" by Dr. and Mrs. J. W. Hayward.

Little Soy Bean, who are you
From far off China where you grew?
I am wheels to steer your cars,
I make cups that hold cigars,
I make doggies nice and fat
And glue the feathers on your hat.
I am very good to eat,
I am cheese and milk and meat.
I am soap to wash your dishes,
I am oil to fry your fishes;
I am paint to trim your houses,
I am buttons on your blouses.
You can eat me from the pod,
I put pep back in the sod.
If by chance you're diabetic,
The things I do are just prophetic.
I'm most everything you've seen
And still I'm just a little bean.

Is your objective to answer all the questions children ask or have them look it up in a book? Or do you take these problems that are of concern to boys and girls and use them to help develop a scientific attitude?

I am thinking of a group of sixth graders who became interested in sound after the music specialist gave a demonstration on woodwind, wind and string instruments. After it was all over one lad asked, "Why were the sounds so different?"

By means of experiments, discussion, and reading from authoritative sources, the children were able to check and draw conclusions. They not only learned that sound is made when something vibrates; that sound travels many miles through air; that sound travels through soil, wood, and other materials; that sometimes the side of a hill or the wall of a building keeps vibrations from going foreward and thereby causes an echo; that the highness or lowness of a note is called pitch. These pupils also learned to be open-minded, not to be hasty in conclusions, to check sources of information for reliability, to observe accurately.

You will agree that we learn best by doing and that first hand experiences are more meaningful. That is the reason the use of demonstrations is so important in science teaching.

Let's consider what constitutes a good science demonstration.

First of all we must have a purpose. The teacher must ask himself, "Will this cause my pupils to think and is the demonstration concerned with life about my pupils? Will this demonstration meet

the needs, interests, and abilities of the learners? Can I make use of community resources to give it more meaning?" Then the children must know and understand the purpose.

The demonstration should be simple. Lack of equipment should not be an excuse. Children can collect materials and with teacher help costs can be kept at a minimum.

Whenever possible children should be encouraged to create their own experiments. Here you have a typical example of a "learning by doing" experience. Pupils have a real need to think, plan, and organize.

Before generalizations are made, more than one demonstration should be done. Simply blowing up a balloon to prove that air occupies space is not conclusive evidence. There should be several demonstrations done in different ways and with different materials.

If you are not cramped for space, the materials used in the demonstration should be left where the children can examine them and do some experimenting themselves.

I wouldn't be too concerned with record keeping. It is far more important that the pupil carry his knowledge in his head. Notebook drawings and filling in manuals are time-consuming activities. We require pupils to write too much. Yes, maybe a statement or two will suffice.

With the science demonstration we find ourselves telling the answers. It would be far better to postpone conclusions and repeat the demonstration. In other words, we should give the pupils time to think out the answers rather than put them in the pupils mouths. "Telling is not teaching." If we tell the pupils we can be sure of the right answer. Did you ever stop to consider that a wrong conclusion opens the way for more teaching and results in a clearer understanding by the pupils?

Certainly the measure of success of the demonstration can be best determined if the children see the relation between the method and the conclusion. Dr. Joe Young West of State Teachers College, Maryland believes that we sometimes present experiments before children have the background ideas needed for interpreting them and that is the major reason why experiments sometimes fail to "get across."

Before starting an experiment, the children should have formulated their plans. It might be something like this.

1. What do we want to find out?
2. What do we need to use?
3. What do we do?
4. What did we find out?
5. How does this apply to everyday living?

My deepest concern today in our school program is the pressure

of time teachers feel. This is true of science teaching. My answer to this is, "take time." Here you have life itself to learn about. What could be more important? Teachers who recognize the child's curiosity about the world uses just one more means of leading his pupils to understand the need for the 3 R's He doesn't pass up an opportunity to use them in science. One pupil said, "We should read to make sure our answers are right."

Another said, "We need to use fractions to explain this."

One teacher who had created an abundance of enthusiasm for experimentation among her pupils had this happen. During the group planning period a member said, "Let's get our reading and arithmetic done so we can experiment."

The crux of our problem is that we feel insecure in teaching something about science's vast storehouse of knowledge. We have reason to be. Yes in college we heard and read about the scientific attitude, the importance of thinking and making generalizations but just how is a teacher going to learn how to use these techniques when she's busy identifying fifty birds not by their common names but by their scientific names in order to meet a graduate requirement. But let's take heart! Pick up courage and really go after our problem. Before we can do this we must swallow our pride, get off our teacher pedestal and admit when we don't know and from there take steps to find out. I believe the best teaching takes place when both teacher and pupil work together to find the answer. You have all had that experience, I know.

Are any of you fisherman? Well, you know the fisherman gets pretty discouraged if he sits and doesn't even get a nibble. But his hopes are raised if he finally gets a bite and then his enthusiasm really rises when he lands that first fish. Energetically the line is baited and a try is made for the second and third and so on. By that time the fisherman's eagerness reaches an all time high and the fish stories really begin to roll in his head.

So it is with the science demonstration. Once you have been inspired the children will be too. Then you'll be off to a flying start and will be saying to yourselves, "Why haven't we done this before?" "What will we do next?"

The success of your science program depends upon your veiwpoint. Glen Blough aptly stated it when he said, "If we are going to keep pupils wondering and questioning, we must wonder too."

SCIENCE IS UNIVERSAL

A Demonstration

What do we want to find out?

What do we need to use?
What do we do?
What did we find out?
How does this apply to everyday living?

Plants

Take a lima bean that has been soaked overnight. With a knife carefully cut around the seed. Remove the outer coat. Notice the tiny plant and the two broad masses of stored food. These become the "seed leaves" of the new plant and nourish it until the roots get started.

St. Patrick's Day

Jimmy said, "I never saw a green carnation before."

That afternoon the teacher brought a stalk of celery and some green vegetable coloring.

Jimmy put water in a glass and added a teaspoon of the coloring. He placed the stalk in the glass.

Within two hours the water had traveled up through the stalk and made the veins green.

The children could see how water rises in plants.

Learning About the South

Some Fifth Graders grew cotton, peanuts, and an avocado plant. They also cared for and learned about their crocodile, Oscar.

Do You Know?

Wild seeds show more striking results when used to test germination than commercial seed.

Toads and Warts

"Quackery, superstitions and perversions may be eradicated through a forthright program of instruction in science."

Teacher Aids

Freeman, Dowling, Lacy, Tippett Helping Children Understand Science, John C. Winston Co.
Arey, Science Experiments for Elementary Children, Bureau of Publications, Teachers College, Columbia University.
Craig, Science for the Elementary School Teacher, Ginn and Company.
Blough, Making and Using Classroom Science Materials, The Dryden Press.
Blough and Huggett, Elementary School Science and How to Teach It, The Dryden Press.
Zim, Trees, A Guide to Familiar American Trees, Simon and Schuster.
Olcott and Putnam, Field Book of the Skies, G. P. Putnam's Sons.
Comstock, Handbook of Nature Study, Comstock Publishing Co., Ithaca, N. Y.

The Storm

Considerable damage to a certain community as the result of a line squall initiated a study of weather. Along came Hurricane Hazel and there was more need for investigation.

Hollow glass block has a pale green fibrous glass screen sealed into the center which reduces heat transmission and excessive brightness and glare. Light directing patterns are built into the block's inner surfaces and partial vacuums on both sides of the green filter keep out much of the sun's heat.

SQUARE ROOT: AN ALGEBRAIC APPROACH

Bernard J. Portz
Saint Louis University, 221 N. Grand Blvd., St. Louis 3, Mo.

Mathematics is not just the acquiring of a technique, nor is the purpose of high school mathematics courses merely the mastery of certain skills. The true teacher of mathematics will also endeavor to give his students an insight into the inner workings of mathematical processes. While, admittedly, the opportunities of imparting such an appreciation to the high school mind are limited, the teacher can, with a little ingenuity, find occasion now and then to make a sally in this direction. The extracting of square root is a process which lends itself to such an attempt.

The square root of a number is that number which when multiplied by itself produces the given number. Expressed algebraically,

$$r^2 = N,$$

where N is the number and r is its root. This is a general formula, true for a root of any number of digits.

But we may also wish to express the root in terms of its digits. If there is but one digit in the root, the simple formula

$$x^2 = N$$

can be used. If the root contains two digits, however, then an algebraic expression should be found which will express adequately the relationship of the digits to the decimal point. Thus for a two-digit root

$$(10x+y)^2 = N,$$

a formula which is readily verified by a few numerical examples.

When the parentheses have been expanded and the terms collected, this form can be conveniently written

$$100x^2 + (20x+y)y = N.$$

How readily this formula lends itself to the solution of an actual problem may be shown by an example. Let N equal 4761. By trial and error, if x is set equal to 7, the first term is too large. But trying x equal to 6 we have

$$3600 + (20 \cdot 6 + y)y = 4761,$$

or

$$(120 + y)y = 1161.$$

Also by trial and error we find the y equals 9, and that the square root of 4761 is 69.

Similarly, for a square root of three digits the formula

$$(100x+10y+z)^2=N$$

can be used. After the parentheses have been expanded, the terms are grouped and factored in such a way that the digits can be determined one at a time. Thus

$$10{,}000x^2+100(20x+y)y+[20(10x+y)+z]z=N.$$

While somewhat more cumbersome, this formula also readily lends itself to the extracting of a square root by trial and error.

If the teacher wishes and has time, he can develop the formula for four-digit square roots, and so forth, or he can develop a general formula for finding square roots algebraically. This latter affords an opportunity, at the same time, to give a practical demonstration of a mathematical induction.

The purpose of the above steps is to pave the way toward showing the connection between this algebraic method of extracting square roots and the method used in grade school. A problem, say with a three-digit root, can be worked by the algebraic method. Then, while the algebraic work process is still on the board, the process can be repeated by lining up the work vertically. If only those quantities which involve the next digit to be found are indicated and the powers of ten are dropped, the result will immediately appear to be practically identical to the grade-school or, perhaps better, the standard arithmetic method.

As an example, let N equal 334,084. Then

$$10^4x^2+10^2(20x+y)y+[20(10x+y)+z]z=334084.$$

Since only the first term is of any significance in determining the first digit (counting from left to right), the second and third terms may be abbreviated as follows:

$$10^4x^2+10^2Y+10^0Z=334084.$$

Thus the work process will be less cumbersome, and the nature of the numerical coefficients is brought out more clearly. By trial and error x is found to be equal to 5, and the equation reduces to

$$10^2(20\cdot 5+y)y+10^0Z=84084.$$

y in turn is found to be equal to 7. The equation then becomes

$$700\cdot 107+[20(57)+z]z=84084.$$

or

$$(1140+z)z=9184.$$

z is found to be 8. Thus the square root of 334,084 is 578.

Below the algebraic steps are rewritten, and then the same work is lined up vertically. Lastly all unnecessary rewriting of digits is dropped.

		5 7 8		5 7 8
$10^4x^2+10^2Y+Z=334084$		334084		334084
$250000+10^2Y+Z=334084$	5	250000		25
$10^2(20x+y)y+Z=84084$	100	84084		840
$700\cdot 107+Z=84084$	107	74900	107	749
$[20(57)+z]z=9184$	1140	9184		9184
$1148\cdot 8=9184$	1148	9184	1148	9184

By comparison the similarity between the algebraic and the standard arithmetic methods is at once evident. Really one can say that the arithmetic method is merely a simplification of the algebraic method, a practical application. And the significance of using the digits in groups of two is seen from comparing the two methods.[1]

Certainly the algebraic method outlined in this paper is too cumbersome to be practicable for daily use. It involves extensive algebraic manipulation and requires increasingly difficult reasoning as the number of digits increases (though once the process is understood, the amount of reasoning is the same as in the arithmetic method). By no means is it intended, therefore, as a permanent working method; it is merely suggested as an interesting diversion from the regular classroom work. And it can be psychologically helpful to the students to know that for a day or two they will be taking an "extra," something for which they will not have to render an account. The chief value, however, lies in giving some insight into the usual arithmetic process and in affording a glimpse into the wider reaches and interrelationships of mathematics.

[1] A point that should be mentioned, but which would not be presented to any class except perhaps the most capable, is the application of the algebraic method to irrational roots. One way to handle such a problem is to use a formula which expresses the relation of the digits of the root to the decimal point. For example, to find $\sqrt{3}$ one can use the formula

$$(x+.1y+.01z+\cdots)^2=N.$$

Eggshell cutter has three razor sharp wheels which are said to score the shell without touching the contents. When held in an egg cup, the neatly opened egg can be eaten directly from its shell.

A PRACTICAL OCCUPATIONAL MONOGRAPH FOR HIGH SCHOOL SCIENCE CLASSES

THEODORE W. MUNCH
University of Texas, Austin, Texas

The acute shortage and need for scientists, science teachers, and workers in technical fields related to science has been brought dramatically to the attention of the American education system in the last few years. One of the stated aims of science education is to develop vocational interests in fields relating to science. This aim is not always fully advanced because of the pressure of developing subject matter content and because of the difficulty in maintaining within easy reach of teacher and student the necessary and pertinent information relating to jobs and professions of a scientific nature.

The purpose of this paper is to inform science teachers of a practical and interesting instrument which can relate science and scientific professions. The occupational monograph to be described is designed to contain in a small compact folder all of the latest materials related to a scientific occupation.

The monograph consists of an $8\frac{1}{2}'' \times 11\frac{1}{2}''$ manila folder into which the data are fastened in semi-permanent form. On the left half of the folder is affixed a series of $5'' \times 7''$ cards, secured by scotch tape on the long edge in such a fashion as to enable the cards to be read on both sides. Each card is taped $\frac{1}{2}''$ below the one preceding it and each card is numbered in the lower right hand corner. With this arrangement it is possible to read any card on either side by lifting the cards above. The scope of the material contained on these cards is as follows:

1. Brief history of the profession
2. Importance of the profession to society
3. The number and sex of persons employed
4. The specific areas of specializations within the profession
5. The related professional and non-professional occupations
6. The tools, machines, and materials used
7. Physical and mental limitations of the occupations
8. The education requirements and experience needed
9. How a position is obtained
10. Salary and working conditions
11. Typical places of employment
12. Other sources of information concerning the occupation

The above information can normally be gathered on 7 to 10 cards.

Opposite the row of cards is affixed an index of the items listed in 1–12 above and the number of the card on which the information can be found. Following this index may be placed pictures of people at work in the professions together with the tools, materials, and machines of the occupation. It is important that the illustrative material

be extensive and as "true-to-life" as possible. The "romantic" aspects of a profession should not be stressed more than they are actually encountered in the occupation.

Finally, pamphets describing the profession may be placed last. The U.S Employment Service, Department of Labor, has many pamphlets which may be obtained through the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C. These are often free or cost about 15 cents. Many industrial concerns also publish materials which are informative, well illustrated, and free.

The advantages of such a monograph are:

1. The monographs are not bulky and may be filed alphabetically in the science room where they are immediately available.
2. All of the pertinent materials are contained in a single folder.
3. New materials may be easily added and old materials easily deleted.
4. The monographs may be assembled by students as projects or extra credit assignments.

THE AAAS COOPERATIVE COMMITTEE ON THE TEACHING OF SCIENCE AND MATHEMATICS

A REPORT ON ACTIVITIES FOR THE YEAR 1954*

WM. HERBERT EDWARDS
629 North Main St., Milford, Mich.

In this report the long, official title of the committee on which I am your representative shall be shortened to simply, "the Committee." Furthermore, the practice will be observed that obtains on the Committee, namely, that the word "science" in this report refers to and includes both science and mathematics.

A year ago Mr. Donald Lentz reported to this convention the Committee's status as of November, 1953. In his report. Mr. Lentz presented the Committee's functions, its composition and its history. The paper was printed in SCHOOL SCIENCE AND MATHEMATICS in the February, 1954, issue. My report, then, is a continuation through the year 1954 of the Lentz report.

For the benefit of the newly initiated in the Central Association may I be permitted a brief explanation of the Committee at this point: Eighteen professional societies have membership on the Committee. The Central Association's representative is elected by the Association's Board of Directors for a three year term. The function of the Committee is to give its attention to major problems in the fields of science teaching at the elementary, secondary, and college

* Presented at the Central Association of Science and Mathematics Teachers at Chicago, November 27, 1954

levels. The Committee's "attention" stems from within the committee, from problems presented to the Committee by the member societies through their representatives, and from persons or agencies not represented on the committee.

Such was the origin of the Committee's program in 1954. Prior to the April 3 and 4 meetings of the Committee this Spring in Chicago, the Scientific Manpower Commission suggested that the Committee join the Commission and the Academy Conference in sponsoring a symposium at the annual meeting of the AAAS in Berkeley California during Christmas week of this year. This symposium would address itself to the problem, "Science Teachers for Tomorrow."

The Committee accepted the invitation on the basis of the urgency for action on the critical shortage of scientific manpower in general and the increasing shortage of science teachers in particular. The acceptance was based, too, on the Committee's practice of sponsoring a symposium at each annual meeting of the AAAS. This acceptance led to a sub-committee of the parties concerned in Chicago on July 24 and 25, 1954. These meetings produced a tentative Action Program.

The intention was that this tentative plan be submitted to the Committee for consideration, study and probable revision, and that this revised form be presented to the Berkeley symposium for evaluation and suggested revision. The tentative plan was the principal item of business in the Committee's meetings in Washington, D. C., on October 14, 15, and 16. The Action plan was given intensive study, it was submitted to a group of experts called in as guest consultants, and it was revised for submission in the Berkeley meeting. In the Spring, 1955, meeting of the Committee, the Action Plan will be put in final form. Means will then be sought to put the plan into effective operation.

No doubt the Plan will experience observations and suggestions dictating revision at Berkeley. In any event the final draft will be publicized nationally. These circumstances presume but an outline of the Action Plan in this report. In summary, the Action Plan is designed to materially reduce the shortage of science teachers. The Plan proposes to accomplish this objective through six avenues of action:

I. Encourage college and university science and mathematics departments to accept teacher education as a major responsibility.
II. Assist in the recruitment of liberal arts graduates and undergraduates for teaching.
III. Assist in interesting high school students in preparation for teaching careers.
IV. Support higher salaries for high school and college teachers.
V. Promote the national recognition of exceptionally able science teachers.

VI. Promote the utilization of consultants in science in areas in which this needed aid is inadequate.

The direct influence of the Committee is known and accepted. Its contacts, reports and publications have extensive currency and genuine respect. The indirect, or "grass roots" influence, were this subject to measure, might prove equally wide. Even in the short period of my stewardship the Committee's influence has been felt in the school in which I teach—by the administration, by the faculty, and by the students. Aye, even by my non-teaching friends.

PROBLEM DEPARTMENT

CONDUCTED BY MARGARET F. WILLERDING

Harris Teachers College, St. Louis, Missouri

This department aims to provide problems of varying degrees of difficulty which will interest anyone engaged in the study of mathematics.

All readers are invited to propose problems and to solve problems here proposed. Drawings to illustrate the problems should be well done in India ink. Problems and solutions will be credited to their authors. Each solution or proposed problem sent to the Editor should have the author's name introducing the problem or solution *as on the following pages.*

The editor of the department desires to serve his readers by making it interesting and helpful to them. Address suggestions and problems to Margaret F. Willerding, Harris Teachers College, St. Louis, Missouri.

SOLUTIONS AND PROBLEMS

Note. Persons sending in solutions and submitting problems for solutions should observe the following instructions.

1. Solutions should be in typed form, double spaced.

2. Drawings in India ink should be on a separate page from the solution.

3. Give the solution to the problem which you propose if you have one and also the source and any known references to it.

4. In general when several solutions are correct, the one submitted in the best form will be used.

LATE SOLUTIONS

2426, 2431, 2434. *C. W. Trigg, Los Angeles, Calif.*

PROPERTIES OF THE PYTHAGOREAN CONFIGURATION

2437. *Proposed by C. W. Trigg, Los Angeles City College.*

Squares are constructed externally on the legs of a right triangle ABC. The joins of the vertices of the acute angles to the remote vertices of the square on the opposite sides intersect in M, and cut AC and AB in B' and A' respectively. Show that:

(1) The segment of either leg adjacent to the right angle is the mean proportional between the remote segments of the legs.

(2) The product of the ratios into which M divides AA' and BB' is equal to the square of the sum of the legs divided by the product of the legs.

(3) The areas of the triangles AMB' and $A'MB$ are in the same ratio as the cubes of the adjacent legs.

Solution by the proposer

(1) Let the squares be $AEFC$ and $BHGC$. Then

$$a=BC=CG=GH$$

and

$$b=AC=CF=FE.$$

From similar triangles,

$$A'C/b=a/(a+b).$$

and

$$B'C/a=b/(a+b).$$

It follows that

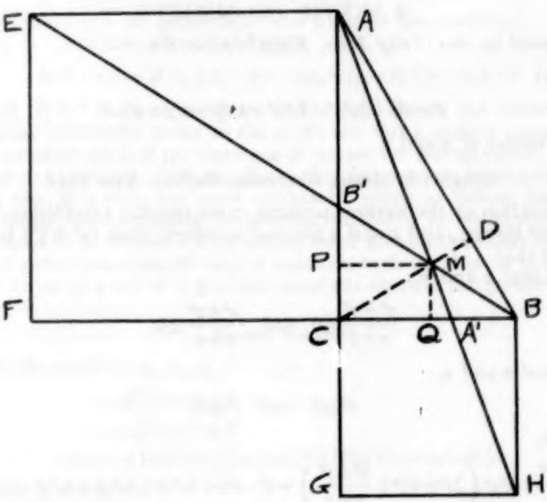
$$A'C=ab/(a+b)=B'C, \qquad A'B=a-A'C=a^2/(a+b)$$

and

$$AB'=b-B'C=b^2/(a+b).$$

Whereupon

$$(A'C)^2=(B'C)^2=(A'B)(AB').$$



(2) From (1), $AB'/B'C=b/a=CA'/A'B$. Draw CM extended to meet AB in D. Then by Ceva's Theorem,

$$(b/a)(b/a)(BD/DA)=1 \quad \text{so} \quad AD/DB=b^2/a^2.$$

Now

$$AM/MA'=AB'/B'C+AD/DB=b/a+b^2/a^2=b(a+b)/a^2.$$

Also

$$BM/MB'=BA'/A'C+BD/DA=a/b+a^2/b^2=a(a+b)/b^2.$$

It follows that

$$(AM/MA')(BM/MB')=(a+b)^2/ab.$$

(3) From (2),

$$AM/AA'=b(a+b)/(a^2+ab+b^2)$$

and

$$BM/BB'=a(a+b)/(a^2+ab+b^2).$$

Let the orthogonal projections of M on AC and BC be P and Q, respectively. Then from similar triangles,

$$MP=A'C(AM/AA')=[ab/(a+b)][b(a+b)/(a^2+ab+b^2)]=ab^2/(a^2+ab+b^2).$$

Likewise,

$$MQ=B'C(BM/BB')=a^2b/(a^2+ab+b^2).$$

Then

$$\begin{aligned}\triangle AMB'/\triangle A'MB&=\tfrac{1}{2}(AB')(MP)/\tfrac{1}{2}(BA')(MQ)\\&=[b^2/(a+b)][ab^2/(a^2+ab+b^2)]/[a^2/(a+b)][a^2b/(a^2+ab+b^2)]\\&=b^3/a^3.\end{aligned}$$

Solutions were also submitted by Richard H. Bates, Milford, N. Y.; A. R. Haynes, Tacoma, Wash.; and Sister M. Stephanie, Lakewood, N. J.

A SEXTIC INEQUALITY

2438. *Proposed by Bro. Felix John, Philadelphia, Pa.*

Show that

$$x^6-x^5y+4x^4y^2-2x^3y^3+4x^2y^4-xy^5+y^6>0$$

for all real values of x and y.

Solution by Aaron Buchman, Buffalo, New York

A consideration of the various possible cases quickly establishes the lemma: If n is an *odd* integer, and x and y are real numbers, then (x^n+y^n) has the same sign as $(x+y)$.

Thus for real x and y,

$$\frac{x^7+y^7}{x+y}\geqq 0 \quad\text{and}\quad \frac{x^3+y^3}{x+y}\geqq 0.$$

But for real x and y,

$$x^2\geqq 0 \quad\text{and}\quad y^2\geqq 0.$$

Therefore,

$$\frac{x^7+y^7}{x+y}+x^2y^2\left(2x^2+2y^2+\frac{x^3+y^3}{x+y}\right)=x^6-x^5y+4x^4y^2-2x^3y^3+4x^2y^4-xy^5+y^6\geqq 0.$$

NOTE: The problem as published had a misprint.

Solutions were also offered by Richard H. Bates, Milford, N. Y.: A. R. Haynes, Tacoma, Wash.; C. W. Trigg, Los Angeles, Calif.; and the proposer.

FUNDAMENTAL INEQUALITY OF ARITHMETIC AND GEOMETRIC MEAN

2439. *Proposed by Dewey C. Duncan, Los Angeles, California.*

If

$$x_1, x_2, \cdots, x_n$$

are positive real numbers, not all being equal, then show

$$\frac{x_1+x_2+\cdots+x_n}{n} > \sqrt[n]{x_1x_2x_3\cdots x_n}$$

Solution by Cecil B. Read, University of Wichita, Wichita, Kansas

This is merely the proof that the arithmetic mean is greater than the geometric mean.

Suppose, since the numbers are not all equal, and the order of arrangement is immaterial

$$x_1 \geqq \text{any other of the numbers,}$$

and

$$x_n \leqq \text{any other of the numbers,}$$

then

$$nx_1 > x_1+x_2+\cdots+x_n > nx_n$$

and if

$$M=\frac{x_1+x_2+\cdots+x_n}{n}$$

$$x_1 > M > x_n.$$

Now let $X=x_1+x_n-M$, hence $X>0$ and consider the numbers.
$M, x_2, x_3, x_4 \cdots X$ which we may call set I

$$MX-x_1x_n=M(x_1+x_n-M)-x_1x_n=(x_1-M)(M-x_n)>0.$$

Now with $M+X=x_1+x_n$ we have $MX>x_1x_n$. Hence the numbers of set I have the same arithmetic mean as the given set, but a greater geometric mean. If we now consider set I, if the numbers of the set are not all equal, M is neither the greatest nor the least of the set. Repeating the process, we can obtain set II, containing two M's with the same arithmetic mean as before, but a greater geometric mean. By continuing the process, we finally arrive at a set of n numbers each equal to M, but with a geometric mean greater than that of the original set. But the geometric mean of these n numbers each equal to M is M, hence the arithmetic mean of a set of n position numbers exceeds the geometric mean of the set.

Second Solution

Consider the numbers $x_1, x_2, x_3, \cdots, x_n$

$$x_1x_2 \leqq [\tfrac{1}{2}(x_1+x_2)]^2$$
$$x_3x_4 \leqq [\tfrac{1}{2}(x_3+x_4)]^2$$
$$x_1x_2x_3x_4 \leqq [\tfrac{1}{2}(x_1+x_2)\tfrac{1}{2}(x_3+x_4)]^2 \leqq [\tfrac{1}{4}(x_1+x_2+x_3+x_4)]^4.$$

Hence, if n is a power of 2

$$x_1x_2x_3\cdots x_n \leqq \left[\frac{1}{n}(x_1+x_2+\cdots+x_n)\right]^n.$$

If n is not a power of 2 consider the set

$$x_1, x_2 \cdots x_n, M, M \cdots M$$

where

$$M=\frac{x_1+x_2+\cdots+x_n}{n}$$

occurs k times, and $n+k$ is a power of 2, then

$$x_1x_2x_3 \cdots x_nM^k \leq \left[\frac{x_1+x_2+\cdots+x_n+kM}{n+k}\right]^{n+k}$$

or, if

$$G = \sqrt[n]{x_1x_2x_3\cdots x_n}$$
$$G^nM^k \leq M^{n+k}$$
$$G^n \leq M^n$$
$$G \leq M$$

the equality holding only if $x_1 = x_2 = x_3 = \cdots = x_n$ which is contrary to hypothesis.

A solution was also offered by the proposer.

EDITOR'S NOTE: In "Higher Algebra, Sequel to Higher Algebra for Schools," W. L. Ferrar, Oxford, 1948, three proofs of the above problem are given and an outline is given for a fourth. The author states this inequality "is appropriate to the top forms in school and to first year classes in universities."

Robert E. Horton, Los Angeles City College, comments: "This problem is merely the statement that the arithmetic mean of positive quantities is greater than their geometric mean. An excellent proof appears in the Sept.–Oct. 1954 issue of the *Mathematics Magazine*, Vol. 28, No. 1, pp. 22–23 in an article by Richard Bellman."

PERMUTATIONS OF THE TEN DIGITS

2440. *Proposed by C. W. Trigg, Los Angeles, Calif.*

There are only two five-digit integers formed from two different digits whose squares minus one million are permutations of the ten digits.

Solution by Richard H. Bates, Milford, N. Y.

1. The two required integers will be permutations of either the *abbbb* or *aabbb* of which there are 450 of the former and 900 of the latter.
2. $1023456789 < N^2 < 9876543210$ hence $31992 < N < 99381$.
3. Any permutation of the digit, zero, and another digit can be eliminated if two zeros are adjacent or if the permutation ends in a zero.

   From these three facts, of the possible 1350 permutations 545 may be eliminated.
4. Any permutation of 3 and another digit in which the permutation begins with at least two 3's will produce a square beginning with two ones. Hence 24 more permutations may be eliminated.

   The total number of remaining permutations is 781 and by means of a calculating machine the following two integers are the only two satisfying the given conditions:

$$56555^2 = 3198468025 \text{ less } 1{,}000{,}000 = 3197468025$$
$$66266^2 = 4391182756 \text{ less } 1{,}000{,}000 = 4390182756$$

A solution was also offered by the proposer.

POWERS OF THE VERTEX OF A TRIANGLE

2441. *Proposed by Nathan Altshiller-Court, University of Oklahoma.*

The product of the powers of a vertex of a triangle with respect to the four tritangent circles is equal to the product of the squares of the radii of the four circles.

Solution by the proposer

Let ABC be the given triangle, (I), (I_a), (I_b), (I_c) its incircle and its excircles relative to the vertices A, B, C, respectively, and let X, X_a, X_b, X_c be the points of contact of those circles with the side BC.

If $BC=a$, $CA=b$, $AB=c$, and $a+b+c=2p$, we have:

$$BX=p-b, \qquad BX_a=p-c, \qquad BX_b=p, \qquad BX_c=p-a,$$

(see, for inst., the proposer's College Geometry, sec. ed., pp. 87–89).

Now the four segments considered are the tangents from the point B to the four tritangent circles, hence the powers of B for the circles are equal to the squares of those segments (*ibid*, p. 191, art. 414b). Thus the product of the four powers considered is equal to

$$p^2(p-a)^2(p-b)^2(p-c)^2.$$

Similarly for the other two vertices of ABC. Hence the proposition (*ibid.*, p. 79, art. 134).

Solutions were also offered by Richard H. Bates, Milford, N. Y. and Sister M. Stephanie, Lakewood, N. J.

AN AREA BISECTOR OF A TRAPEZOID

Proposed by V. C. Bailey, Evansville, Indiana

2442. Find an expression for the length of the line, parallel to the parallel sides and bisecting the area of a trapezoid, in terms of the parallel sides. One side of the trapezoid is perpendicular to the parallel sides.

Solution by Millard E. Agerton, Preston, Ga.

Let: m be the length of the line segment parallel to the parallel sides of the given trapezoid; a be the length of the upper base, b be the length of the lower base, h be the altitude and A the area of the given trapezoid; and: s be the altitude and A_1 the area of the lower, and A_2 the area of the upper of the 2 equal area trapezoids formed from the original by drawing m.

1st: Since

$$A_1=A_2: \qquad \tfrac{1}{2}s(m+b)=\tfrac{1}{2}(h-s)(m+a).$$

From which:

$$s=\frac{h(m+a)}{2m+a+b}. \tag{1}$$

2nd: Since

$$A_1=\tfrac{1}{2}A: \qquad \tfrac{1}{2}s(m+b)=\tfrac{1}{4}h(a+b);$$

or:

$$2s(m+b)=h(a+b)$$

From this:

$$s=\frac{h(a+b)}{2(m+b)}. \tag{2}$$

3rd: Substituting the value of s from (2) in (1):

$$\frac{h(m+a)}{2m+a+b}=\frac{h(a+b)}{2(m+b)}.$$

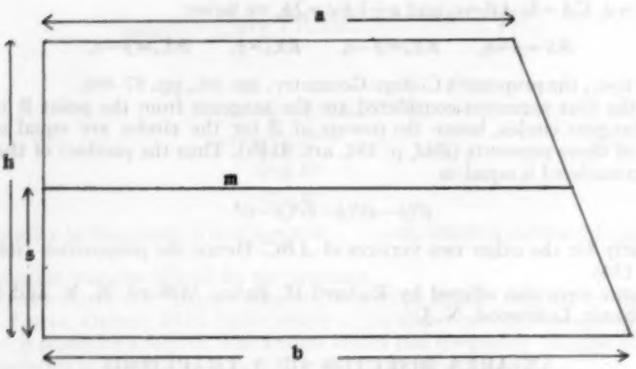
From this:

$$2m^2=a^2+b^2$$

and:

$$m=\tfrac{1}{2}\sqrt{2(a^2+b^2)} \quad \text{or} \quad m=\tfrac{1}{2}\sqrt{2a^2+2b^2}.$$

(since only the positive value of m is significant here)



Solutions were also offered by Richard H. Bates, Milford, N. Y.; Suessa B. Blaine, Washington, D. C.; Aaron Buchmann, Buffalo, N. Y.: C. H. Butler, Kalamazoo, Mich.; Richard M. Dey, Petersburg, Va.; Harvey Fiola, Wahpeton, N. D.; Garret Freeleigh, Sheldrake, N. Y.; A. R. Haynes, Tacoma, Wash.; George Hays, Tuxedo Park, N. Y.; Robert E. Horton, Los Angeles, Calif.; Ezekiel W. Mundy, Rochester, N. Y.; O. T. Shannon, Pine Bluff, Ark.; Robert Steinhart, Montclair, N. J.; Isaac N. Stout, Key West, Fla.; James F. Ulrich, Arlington Hts., Ill.; Walter R. Warne, St. Petersburg, Fla.; Mrs. Walter Warne, St. Petersburg, Fla.; and Webster Wells. St. Augustine, Fla.

W. R. Warne and R. M. Dey refer to an arithmetical solution of the problem in the Key (p. 207, problem 101) of Joseph Ray's "New Higher Arithmetic" published in 1881.

STUDENT HONOR ROLL

The Editor will be very happy to make special mention of classes, clubs, or individual students who offer solutions to problems submitted in this department. Instructors are urged to report to the Editor such solutions.

EDITOR'S NOTE: For a time each student contributor will receive a copy of the magazine in which his name appears.

For this issue the Honor Roll appears below.

2439. *Lee Dresden Goldberg, Hillsdale, N. J.*

2442. *Edward F. Sidor, Crawfordsville, Ind.*

PROBLEMS FOR SOLUTION

2461. *Proposed by Cecil B. Read, University of Wichita, Wichita, Kan.*

Find, without using logarithms, the limit as x approaches infinity of $2^x/e^{x^2}$.

2462. *Proposed by Julian H. Braun, U. S. Army, Aberdeen Proving Ground, Md.*

In a certain college F per cent of the freshman class are men having 1-A draft classification. A directive exempts from the draft those "1-A's" who are in the upper U per cent of their class. The army calls all 1-A men available under the above restriction. Now, of course, after the first call, some 1-A students who were in the upper U per cent are then beneath the dividing line in the reduced class. Supposing the army continues to call men as far as it can go under this system, in what upper percentile group of the original class would a 1-A student have to be in order that he be exempted from the draft? (Assume a uniform percentile distribution of 1-A's on the ranking scale of the original class.)

2463. *Proposed by Richard H. Bates, Milford, M. Y.*

Through any interior point P in triangle ABC, lines are drawn parallel to the three sides of the triangle, dividing these sides onto three segments each. If the center segments of sides a, b, and c, are denoted by a', b', and c' respectively, show that

$$a'/a+b'/b+c'/c=1.$$

2464. *Proposed by C. W. Trigg, Los Angeles City College.*

In triangle ABC, if $\angle A=4\angle B$, find the relationship involving the sides. Show that, in particular, if $b=c$, then $a=b\sqrt{3}$.

2465. *Proposed by C. W. Trigg, Los Angeles City College.*

In Circle O, central angle COE is less than 90°; OE extended meets the circle again in A and the tangent at C and D. The parallel to CD through A meets the circle in B. Express angle ABD in terms of angle COE.

2466. *Proposed by John Spalic, Springdale, Pa.*

Prove the identity:

$$\sin(x+y)\cos y+\cos(x+z)\sin z=\sin(x+z)\cos z+\cos(x+y)\sin y.$$

BOOK REVIEWS

THE PERMANENT REVOLUTION IN SCIENCE, by Richard L. Schanck, *Chairman, Department of Sociology, Bethany College; Lecturer, Carnegie Institute of Technology.* Cloth. Pages xiv+112. 13.5×21.5 cm. 1954. Philosophical Library, Inc., 15 East 40th Street, New York 16, N. Y. Price $3.00.

Some fifteen or more years ago an occasional physical scientist stepped out of his specialist-bounds to speculate on the use of the principle of mobile equilibrium in the study of social and economic changes. He never ventured far for he knew the professional hazards of such out-of-bounds projection. If any of the readers of this review still have an urge to that type of browsing this book offers encouragement.

In the author's judgment the popular conception of science, as cause and effect as applied to individuals, is considered but a vestigial fragment of modern science's concern with systems in which the individual element is all but lost in the mass. Starting with the shift from the mechanical principles of Newton to the later thermo dynamics, the phase rule and mass action systems he traces the slow but, to him, evident permeations of those patterns into biology, psychology and social studies; and even ethics.

Chapter titles, after a Foreword and Introduction, list: From Speculation to Experiment; The Emergence of Physics (concerned with mechanism and the individual); Emergence of Chemistry (addressed to notions of systems); Emergence of Biology (assessing the system and its field); Approach to Personality (Freud's psycho-analytical pattern); Telic Sociologists (committed to continuous progress); Problem of Ethics (ethics as an aspect of the permanent revolution) and the last chapter on The Institute of Experimental Method.

For the author a change in any field is but the disequilibrium of many factors which might be called the "interpenetration of opposites" and in general helpfully assessed by general rules applicable to systems. Two characteristics of this change approach are: the "laws" are formulated as leading to "probilities" and not certainties as related to the individual and; variations in what might be called "intensities" of these opposites making possible the concept of "trends" so helpful in the fields of the life and social sciences.

This book should certainly bid for the attention of author Schanck's fellow sociologists and the philosophers, as well as the natural science specialists.

Those who chafe under the restrictions of over-departmentalization may, in this, sense a breath of the fresh air of greater freedom that crashes some of the boundary fences of the specialists.

B. CLIFFORD HENDRICKS
Longview, Wash.

LABORATORY STUDIES IN BIOLOGY, by Addison E. Lee and Osmond P. Breland, *University of Texas.* 253 pages. 1954. Harper and Brothers, New York, New York.

A laboratory manual that should require the minimum of lecturing before the work is started in the laboratory. Explanations as to instructions seems to be complete with what is to be learned well defined.

Most drawings are large and complete, but not cluttered with excessive lines. There seems to be a degree of accuracy in all drawings. Labeling should be easy but there are no lines to any specific part of the drawings. By the time the student completes reading and study, of any particular unit and then is able to label the many illustrations he should have a basic understanding of the unit.

There has been a careful selection of the examples used for study. Most of those selected are typical of those used by most schools in a general biology course.

This manual may be used as a companion with Principles of Biology by Whaley and others, or it may be successfully used in any general biology course.

NELSON L. LOWRY

PRINCIPLES OF BIOLOGY, by Gordon W. Whalen, Osmond P. Breland, Charles Hemisch, Austin Phelps and Glenn S. Rabideau, *University of Texas.* Cloth. 1954. ix+649 pages. Harper and Brothers, New York, New York. Price $6.00.

This book is a complete course in biology. Principles of biology have been fully covered. There seems to be a good balance, without too much emphasis on any one principle but a development of each. The material in the text is rather detailed.

Technical terminology is kept to a minimum throughout the book, but specific terms have not been omitted in the text. Where necessary, they are used. Explanations are complete so that any student that completes such a course, using this book should have an understanding of the principles of biology and life itself. There are many meaningful illustrations. They are usually simple and are used to an advantage to supplement the text. In places additional illustrations might be helpful.

The text is developed in essentially complete sections so that anyone desiring to rearrange the order of sequence can do so without trouble. This text that should be useful at the College level for any student. It is the result of a number of years work on the part of the authors in developing biology units as teachers of biology at the University of Texas.

NELSON L. LOWRY

INTRODUCTORY COLLEGE MATHEMATICS, by Adele Leonhardy, *Chairman of the Mathematics Department, Stephens College.* Cloth. Pages ix+459. 15×23 cm. John Wiley & Sons, Inc., New York, N. Y., 1954. Price $4.90.

This book is designed primarily to meet the needs of the college student who does not plan to specialize in mathematics or the related sciences. Its purpose is twofold: (1) To develop for the student the mathematical concepts and techniques needed in the program of general education. (2) To present mathematics itself as one of the areas of general education.

According to the author, the book presupposes a minimum of one year of high school algebra and one year of plane geometry. However, it seems to the reviewer that the general maturity required to understand the broad mathematical concepts and the thinking necessary to see into the nature of mathematics itself as exemplified in this book would require a highly selected group of students. It

represents more than a course about mathematics but represents a course in mathematics as far as beginners are concerned.

The first chapter attempts to answer, for the student, the question, "What is Mathematics?" The chapters in turn treat The Algebra of Numbers and Numbers in Exponential Form. In the chapter on Measurement and Comparison, an excellent treatment of significant figures is given. Other chapters treat The Comparison of Quantities. Functional Relationships, and Variation. A number of formulas and problems from the differential and integral calculus are included in the chapter on The Rate of Change of a Function. Other portions of the book consider Exponential and Logarithmic Functions, Periodic Functions, and Simple Statistical Methods.

Each chapter is supplied with an abundance of exercises and problems which are obviously taken from many areas. Also, bibliographies at the end of each chapter furnish lists of books and periodicals sufficiently varied in scope and difficulty to provide for a wide range of interests and levels of work.

It is stated, in the preface, that the material is intended for a three-to-five hour course containing two semesters. The book merits careful consideration by anyone looking for a text of this type.

CLYDE T. MCCORMICK
Illinois State Normal University

OUTLINES OF ORGANIC CHEMISTRY, by E. J. Holmyard, *late scholar and research student of Sidney Sussex College, Cambridge.* Cloth. Pages vii+492. 12.5×18.25 cm. 1954. Edward Arnold Publishers Ltd. London. Price 3.50.

This text-book in organic chemistry makes use of the English method of approach to organic chemistry. The main emphasis is on classification and types of reactions. Only limited attention is given to electronic concepts and to the mechanism of reactions.

The book is divided into five parts—

I. History, (methods of analysis and elementary theory)
II. More advanced theory
III. Aliphatic compounds
IV. Cyclic compounds
Cabocyclic compounds
V. Cyclic compounds
Heterocyclic compounds
VI. Organic compounds of metals, fluorine, silicon

The text is well organized and is easily read. In the author's preface to this his third edition, he states: "Many additional compounds and reactions are described, and applications of industrial or therapeutical interest are mentioned. . . . A new chapter has been added on organic compounds of metals, fluorine, and silicon." Thus the modern topic of silicones is very briefly treated. However, he fails to consider many of the recent synthetic fibers, such as orlon and dacron.

For a teacher interested in the classical type of approach to organic chemistry as was used in American Colleges some thirty years ago, this would be a textbook that should be given consideration. The reviewer sometimes wonders if we in America have not gone too far in the emphasis on theory in our beginning organic chemistry courses.

GERALD OSBORN
Western Michigan College
Kalamazoo, Michigan

KEY TEXT IN CHEMISTRY, by V. R. Rawson, *Chairman of Science Department, Senior High School, White Plains, New York.* Paper. Pages x+342. 12×18.5 cm. 1954. Jeystone Education Press, 222 Fourth Avenue, New York City. Price $0.75.

This text is described in the preface "as a supplementary study aid, for systematic recapitulation and review throughout the course." The style used is question and answer. One is reminded of the catechism style with which we were all familiar as children. The preface also emphasized that the aim "is to present the essential facts and ideas of high school chemistry in the simplest, most functional, and most compact form compatible with accuracy, clarity, and complete coverage of the course. The material in this book is as comprehensive as that found in the standard full length chemistry text for high schools."

The form of the book is good. The type has been well selected and is easily read. Illustrative material has been well chosen. At the end of each chapter is found a self testing exercise. The appendix is rather complete and contains in addition to needed tabler, an informative tabulation of sixty great chemists and sets of examination questions as prepared by the New York State Regents.

In spite of the fact that the author says "every effort has been made to present here the most modern developments in chemistry coming within the scope of the elementary scope," he gives only the Arrhenius concept of acids and bases and fails to include either the more modern Bronsted or Lewis definitions.

If a student desires a compact and easily read review outline in chemistry he should plan to obtain this book. Students taking Freshman College Chemistry after an elapse of some time would find this text an excellent review reference.

GERALD OSBORN

WORKING WITH NUMBERS, Teachers Edition, Books 1, 2, and 3, by Joyce Benbrook, *Associate Professor of Education, University of Houston;* Cecile Foerster, *Supervisor, Primary Grades, Houston Public Schools;* and James T. Shea, *Editorial Consultant.* Paper. Book 1, 149 pages. 20.5×28 cm. Paper 48 cents, Text $1.24. Book 2, 20.5×28 cm. Paper 48 cents, Text $1.41. Book 3, 20.5×28 cm. Paper 48 cents, Text $1.41. The Steck Company, Austin, Texas.

The Steck workbooks for children should have the attention of all teachers and supervisors of the elementary grades. A teacher's edition is provided for each grade. This gives the theory of instruction and provides directions for presenting each new concept and skill to be mastered. The books for the children range in size from 112 pages to 128 pages, are put up in many colors, with pictures of toys, animals, fruits, coins, etc. This illustrative work was done by Betsy Warren. Each page illustrates a new idea or provides an interesting review of previous work. After three years the student will be able to do all simple arithmetic with three-place numbers, including addition and subtraction of problems involving the use of dollars and cents. The child learns to tell the time of day, to use the telephone, read license plates, and do other practical problems. He learns to read and interpret mathematical language, and it has all been fun.

Elementary teachers will also find the Steck Worktext Catalog of much value for all subjects of instruction.

G. W. W.

LIFE ADJUSTMENT EDUCATION IN ACTION. Edited by Franklin R. Zeran. Cloth. 541 pages. 14.5×22 cm. Chartwell House Inc. 280 Madison Avenue. New York 16, New York. 1953.

This book is further evidence of the attempt to focus attention on "Life Adjustment Education." In 1947 a Commission on Life Adjustment Education for Youth consisting of nine members was appointed for a three year period. Its report called "Vitalizing Secondary Education," which appeared in 1950, was primarily a report on how local schools had developed programs designed to serve all youth as effectively as possible.

The twenty-four chapters in this book were written by specialists in the areas covered. Twenty-seven different people are listed as authors and co-authors.

The chapter on "Science in Life Adjustment Education" was written by Dr. Philip G. Johnson who is now at Cornell University. This chapter includes a

brief discussion of nature study, general science, biology, chemistry, and physics in life adjustment. Science teachers may be interested in Johnson's "Checklist for Determining Life Adjustment Values of Science Instruction."

Some of the other chapters are entitled, "Life Adjustment and Elementary Education, Life Adjustment Education and the Community, The Curriculum in Life Adjustment Education, Instructional Materials in Life Adjustment Education, Putting the Program in Action." There is also one chapter on each of content areas commonly taught in elementary and secondary schools.

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LABORATORY TECHNIQUE IN BACTERIOLOGY, by Max Levine. Cloth. 413 pages. 14.5×21.5 cm. The Macmillan Company, 60 Fifth Avenue, New York 11, New York. 1954.

This is the third revision of a book originally published in 1927. The basic exercises in this edition have been rearranged into eight categories—(1) methods of sterilization (2) starving techniques for determination of morphology (3) preparation of culture media (4) the cultural characteristics of microorganisms or biochemical properties of bacteria (6) effects of environmental factors (physical and chemical on microorganisms) (7) quantitative estimation of bacteria and (8) the phenomenon of agglutination and techniques for its detection. The form of the exercises is like that of earlier editions.

The author states that the scientific names used in this edition are in conformity with the 1948 edition of Bergey's Manual of Determinative Bacteriology.

The approximately 100 pages of appendices contain (A) Dichotomons Keys for Identification of Bacteriology (B) Preparation of Standard and Special Culture Media (C) Preparation of Staining Solutions and Special Staining Methods (D) Tests and Reagents for Metabolic Products (E) Glossary of Descriptive Terms.

Although this book is intended for beginning students in bacteriology, it is an excellent source of teaching ideas and useful information for high school science teachers.

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HUGH ROY CULLEN, A STORY OF AMERICAN OPPORTUNITY. By Ed Kilman, *editor of the Houston, Texas, Post* and Theon Wright, *newspaper man and writer.* Illustrated by Nick Eggenhoffer. Cloth. Pages viii+376. 15.5×22.5 cm. 1954. Prentice Hall, Inc., 70 Fifth Ave., New York 11, N. Y. $4.00.

This might be correctly labelled "A True Tall Tale from Texas." It is the story of a boy who, at the age of twelve, quit his fifth grade school work to aid his mother in the support of a broken home. Within the next thirty years he changed his basic business fields three times after attaining success in each. In the fourth decade of his life his assets had reached a figure of hundreds of millions of dollars but he was still as active as in his younger years. He had become one of the "Oil Barons." As he approached his "three score and ten" he was well into a program of philanthropic "sharing with his people the amazing fruits of his adventures." These philanthropies that "have benefitted his fellow-man regardless of race, creed or color" have, to date, involved 93% of his holdings. His explanation is, "We want to see our money spent, while we can enjoy the spending. Why wait?"

Even before his entry into the oil fields, he had shown a growing concern with a second vocation. After a fistic encounter with a local dictatorial official in a pioneer Oklahoma village he thereafter kept a critical eye upon public officials, especially as their programs related to the world of business. That interest grew, in his later years, into virtually a crusade against threats to his notion of the "American kind of government" as labelled by "welfare state," "creeping socialism," and "internationalist influence." His biographers very frankly state, as a final product of his civic activity, that "Roy Cullen . . . engineered the revolt

. . . for the victory . . . in the Chicago (convention) in July . . . and ultimately for the landslide at the national elections in November of 1952."

This, then, is a biography, entirely lauditory, obviously less than objective, with the senior author, editor of the Houston paper which has been very consistently a supporter of the biographer. The reader may, understandingly, wonder, at times, as to how much in the junior author's first draft may have been blue penciled before it reached the compositor. However that may be, it has a sustaining interest-appeal to its end. While it is a valid illustration that "It did happen here," one needs to remember that "one swallow does not make a summer." Is this a TYPICAL American success story?

B. CLIFFORD HENDRICKS

SUMMER MATHEMATICS INSTITUTE

The *1955 Summer Institute for Mathematics Teachers* will be held in air-conditioned classrooms at the University of Oklahoma in Norman, Oklahoma from June 6 to June 17. Teachers may attend either week (one hour credit) or both weeks (two hours credit). The fee is $15 for one week or $25 for two weeks—either credit or non-credit. Official certificates of attendance will be issued. Dormitory accommodations are available at $2 per night or $10 per week.

Leaders in the teaching of Elementary, Junior High School, High School, and beginning College Mathematics will be on hand to assist teachers with individual problems related to both classroom procedures and subject matter. Material for the interest and enrichment of standard courses will be provided.

If you or any of your colleagues are interested, please send a post card now to F. Lee Hayden, Short Courses and Conferences, the University of Oklahoma, Norman, Okla.

DUPONT FELLOWSHIPS FOR TEACHERS OF CHEMISTRY

Saint Louis University has been awarded an $8,100 grant from E. I. du Pont de Nemours and Company for the general support of its Institute for the Teaching of Chemistry, it was announced today by Dr. Theodore A. Ashford, Director of the Institute.

A grant of $4,500 will provide twelve fellowships for chemistry High School and Junior College teachers, enabling them to attend the University's Institute for the Teaching of Chemistry in the summer of 1955. The fellowships provide tuition of $100 and a living allowance of $180 for the student.

A grant of $3,600 will provide two fellowships for the support of qualified recent college graduates, who wish to work toward a Master's of Science in the Teaching of Chemistry, during the academic year 1955–56. The year's study will prepare recipients of the fellowships to teach chemistry, physics, or mathematics in a secondary school. Each fellowship will provide $450 tuition and a stipend of $1,200 for the student.

The Institute for the Teaching of Chemistry was founded in 1950 to meet the rising need for correlation between the fields of education and science. Up until the formation of the Institute, there was no program designed to fill the needs of the secondary school teachers, since the traditional research Master's degree in Chemistry is directed toward the preparation of the professional chemist rather than the teacher. The Institute is administered by the Chemistry Department with the cooperation of the related science departments and the department of Education.

The Institute's program consists of three phases. It offers a B.S. degree in the Teaching of Chemistry; an M.S. Degree in the Teaching of Chemistry, and a six week Summer Program for M.S. degree candidates and for in-service training of teachers.

Qualified applicants may write directly to: Dr. Ashford, (Director of the Institute For The Teaching of Chemistry), Saint Louis University, for further information concerning the fellowships and a bulletin describing the Institute.